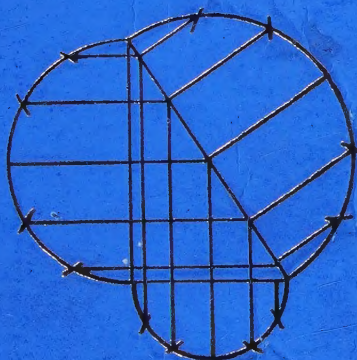


PRACTICAL TREATISE
FOR
BOILERMAKERS



I. J. & H. HADDON



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A PRACTICAL TREATISE

ON

BOILERMAKERS

BY

JOHN W. BRYAN, M.A., OF ST. JOHN'S COLLEGE, CAMBRIDGE, AND
OF THE ROYAL NAVAL COLLEGE, GREENWICH, AND OF THE
ROYAL MILITARY COLLEGE, SANDHURST, AND OF THE
ROYAL COLLEGE OF ARTILLERY, WINDSOR.

A PRACTICAL TREATISE FOR BOILERMAKERS

BY

"BOILERMAKING"

BY

L. J. R. HADWIN

Principal, Glasgow School of Art.

Author of "The Art of the Potter."

LONDON:

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A PRACTICAL TREATISE FOR BOILERMAKERS

CONSISTING OF

*GEOMETRY, DEVELOPMENT OF CYLINDERS, CONES
AND OTHER FIGURES; TEMPLATE MAKING, THE
MANIPULATION OF PLATES AND BARS, TABLES
OF DIAMETERS AND CIRCUMFERENCES, AND MANY
NOTES, RULES, AND FORMULÆ NECESSARY TO
THOSE ENGAGED IN THE TRADES EMBRACED IN
THE TERM*

“BOILERMAKING”

BY

I. J. & H. HADDON

Practical Boilermakers

FOURTH EDITION.

RE-PRINT.

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BLACKSMITHS AND STRUCTURAL WORKERS.

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1975.

PREFACE

TO THE

FIRST EDITION.

In the year 1900 we published a small Treatise for the use of Boilermakers, and during the twelve years it was before the public we were the recipients of numerous complimentary letters from all parts of the world. Profiting by our experience during that time, and being so encouraged by the reception accorded our first efforts towards the advancement of the practical knowledge of the journeymen and apprentices in the trades covered by the term "Boilermaking," we decided that instead of printing a further issue of that work we would devote our spare time to the compiling of a new and larger Treatise.

The result of our labour is now presented in the form of this work, and we trust it will be received in the light of an endeavour to assist the workman as such, without in any way pretending to encroach upon the department of the designer.

Immense strides have of late been made in the direction of technical education, employers being fully alive to the fact that the man who has the most complete knowledge of his trade is the most profitable to them, and consequently they lend their support to the progress of technical classes, and in very many cases encourage their apprentices to attend them. One of the leading features of technical study is the elimination from the workshop of all rule-of-thumb methods, the instruction given being based on sound scientific principals from which are evolved methods at once simple, and accurate.

In the rush of piece work, a system by which so much of the iron and steel construction trade of the country is conducted, there does not seem to be sufficient time in the workshop for the apprentice to study the problems met with in his daily work. It therefore becomes essential that he should study these in his spare

moments, for though an apprentice has a moral right to expect the journeymen to impart such information as may be needed, it is this piece work system that oftens makes it impossible for the journeymen to devote the time in working hours to the assistance of the apprentice.

The "Boilermaking" industry is now so split up into sections so far as the workmen are concerned, such as Plating, Rivetting Caulking, etc., that there is a tendency for men to become specialists in one grade of the work and to have a comparatively poor knowledge of the remainder of their own trade, and when it is remembered that even this sectionising is still further divided in the Shipbuilding trade, especially amongst the Platers who work in squads, one being the marker off, another the puncher, and so on, it will be seen that for such a system to be extended to the apprentices will ultimately mean that we shall have few men who can claim a complete knowledge of the whole industry, and it is to avoid this that we strongly advise the apprentices, whatever grade of work they may be at in the workshop, to study their trade from every point of view and in this way become fitted for any position the trade may offer.

In the study of developments great assistance will be derived from the making of models, either in light cardboard or sheet muntz metal, the latter being particularly suitable for this purpose, and when neatly made become pleasing ornaments. We have made many such from templates drawn on paper, and the fruits of our study and experience are presented in this volume.

Many correspondents during the last twelve years have requested us to include tables of diameters and circumferences in any future work we may issue, and these we have carefully considered. We felt that to occupy numerous pages with tables when a simple rule for working out the same results appeared to us to be all that a workman needed, would not be consistent with our previously expressed view that technical education does not mean carrying reference tables in the pocket, and we determined that if we could compile a table within the space of a few pages we would do so, but not otherwise. We have therefore great pleasure in including in this volume, tables of Diameters and their

Circumferences for every $\frac{1}{16}$ th of an inch diameter up to 144ft., all calculated to the nearest $\frac{1}{32}$ nd part of an inch in circumference and taking up but *two* pages. If these tables (A and B) were compiled in the usual form they would take up over 200 pages.

As tables of Diameters and their circumferences are not suitable for finding the Diameter from the Circumference, we have also included two pages of tables for this purpose, tables C and D being compiled to give the Diameter for any Circumference from $\frac{1}{8}$ th of an inch up to 200ft., all calculated to the nearest $\frac{1}{32}$ nd part of an inch, and rising by eighths of an inch in circumference. These tables if compiled in the usual form would require about 150 pages, from which it will be seen the four tables represent over 350 pages of the usual style of compilation.

As a final word to the apprentices, remember you are to be the future journeymen to whom the nation will look to do your part in maintaining her position in the industry, and as the designers advance, so must the workmen, and to that end it is essential you should endeavour to become masters of your trade, competent to undertake any piece of work that may be put before you. Trusting these pages will be of some assistance in that direction, and also a help to the journeymen.

I. J., & H. HADDON.

Cardiff, 1913.

PREFACE

TO THE

SECOND EDITION.

The extensive circulation enjoyed by the first edition of this work, and the numerous letter of appreciation received have been a source of great pleasure and encouragement. We feel assured that though this (the second) edition is issued at an advance in price, owing to the increased cost of production, the workmen and the apprentices engaged in the Boilermaking and Shipbuilding Industries will continue to avail themselves of the advice and information it contains.

I. J., & H. HADDON.

March, 1920.

PREFACE

TO THE
THIRD EDITION.

With the most helpful co-operation of the Authors, who were desirous that this work should become the property of The United Society of Boilermakers, Shipbuilders and Structural Workers we have acquired the copyright, and also that of the "Tables of Diameters and their Circumferences," from Messrs I. J. & H. Haddon.

In the year 1900 a small Treatise was published for the use of Boilermakers, which resulted in numerous complimentary letters being received from all parts of the world. Profiting by their experience, and encouraged by the reception accorded their first efforts towards the advancement of the practical knowledge of the journeymen and apprentices in the trades covered by the term "Boilermaking," the authors decided, in 1912, that instead of printing a further issue of that work they would devote their spare time to the compiling of a new and more comprehensive Treatise.

The result of that labour was published in a First Edition, and in 1920 as a Second Edition. That issue having run out, this becomes the Third Edition.

Immense strides have of late been made in the direction of technical education, the Government, Employers, and Trade Unions, lending their support to the progress of technical classes, and in most cases to-day, apprentices are allowed time off their work with payment in order to attend approved classes, and this leads us to the firm belief that the value of this work will be seen and appreciated, even more than hitherto.

It is hoped that this work will continue to be of help to our members, and particularly to our apprentices to whom we would utter this final word. "You are the future journeymen upon whom the nation will rely to maintain her position in the industry. As the designers advance, so must the craftsmen, and to that end it is essential you should endeavour to become masters of your trade, competent to undertake any piece of work that may be put before you."

Knowledge is power.

EXECUTIVE COUNCIL.

Newcastle, November, 1947.

A PRACTICAL TREATISE

FOR

BOILERMAKERS

PROBLEM 1.

To bisect a given straight line AB.

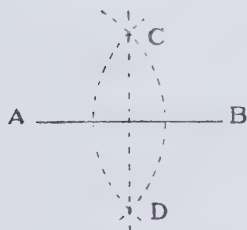


Fig. 1.

From the ends of the line A and B as centres, and with any radius greater than half AB describe arcs intersecting at C and D. A line drawn from C to D will bisect the line AB. Both arcs must be described with the same radius.

If the line AB is of great length set off from each end equal distances in order to reduce the portion to be bisected with compasses.

PROBLEM 2.

To bisect an arc AB.

Treat this problem as though AB were joined by a straight line, then CD will bisect the arc in E, the process being the same as in Fig. 1.

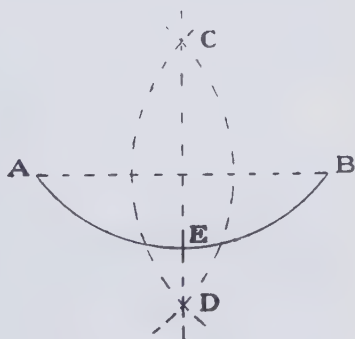


Fig. 2.

PROBLEM 3.

At a given point in a straight line AB, to draw a line perpendicular to AB.

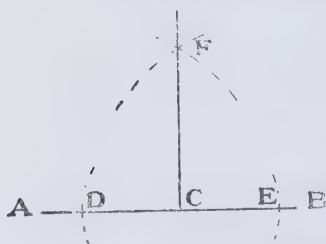


Fig. 3.

From the given point C with any radius within the limits of the line AB describe arcs cutting AB in D and E, then from D and E with any radius greater than CD describe arcs intersecting in F. Join FC which will be the perpendicular line required.

PROBLEM 4.

At the end of a given straight line AB, to draw a line perpendicular to AB.

From B as centre with any radius less than BA describe an arc CD, and from C with the same radius cut the arc CD in E, then from E with the same radius describe the arc F. From C draw a line through E cutting the arc F and G. Join GB which will be perpendicular to AB.

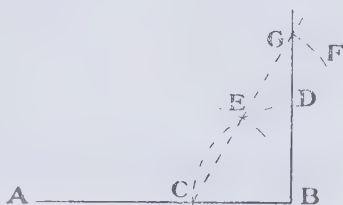


Fig. 4

PROBLEM 5.

From a given point C above the line AB, to draw a line perpendicular to AB.

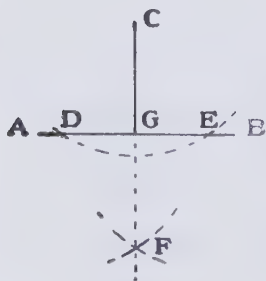


Fig. 5

From C with any radius greater than CG, but less than CA or CB describe an arc cutting the line AB in D and E, and from D and E with any radius describe arcs intersecting at F. A line drawn from C towards F meeting the line AB at G will be perpendicular to AB.

PROBLEM 6.

From a point C above or nearly above the end of the line AB, to draw a line perpendicular to AB.

Draw any line CD at an angle to AB, and bisect CD in E, then from E with EC radius describe arc CFD. Join CF which will be perpendicular to AB. Should the point C be in such a position that the arc CD does not cut the line AB, produce AB until it cuts the arc CD in F. Join CF as before.



Fig. 6.

PROBLEM 7

To draw a line parallel to a given line AB.

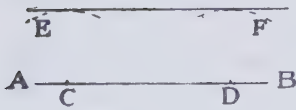


Fig. 7.

From any two points C and D, and with the same radius describe arcs E and F, then a straight line drawn just touching these arcs will be parallel to AB. Should it be

required to have the line a given distance from AB let that distance be the radius of the arcs E and F.

PROBLEM 8.

To bisect an angle ABC.

From the point B with any radius within the figure describe an arc DE, and from D and E with any radius greater than half DE describe arcs intersecting at F. Join BF which will bisect the angle ABC.

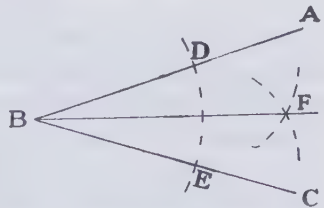


Fig. 8.

PROBLEM 9.

To trisect any acute angle ABC.

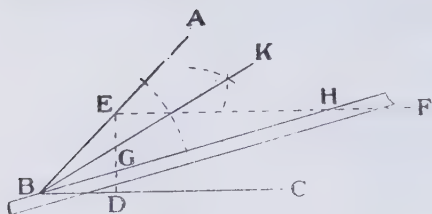


Fig. 9.

There has not yet been found a purely geometrical solution to this problem, in fact it is regarded as one of the impossibilities of geometry. The following method will be found

perfectly accurate, but it is partly geometrical and partly mechanical.

Let ABC be the angle to be trisected. At any point D on BC draw a line perpendicular to BC, meeting AB in E; from E draw EF parallel to BC. Set off on a straight-edge two points G and H, distant apart equal to twice BE, then apply the straight-edge to the figure in such a position that when one point lies on EF, and the other point on ED, the straight-edge shall also engage exactly with the point B.

A line drawn through HGB will be one division of the trisection. Bisect the angle ABH by the line BK, which will complete the figure.

The geometrical difficulty, or rather impossibility, in this problem is to find a means to set out the line BH in such a position that the portion GH, forming the hypotenuse of the right-angled triangle HEG shall be equal to twice BE the hypotenuse of the right-angled triangle EDB.

PROBLEM 10.

To find the centre of a circle by internal drawing.

From any two points A and C approximately opposite each other, and with radius greater than half the diameter, describe arcs intersecting in E and F; join EF. From any two points B and D describe similar arcs intersecting in G and H; join GH. Where GH cuts EF will be the centre of the circle.

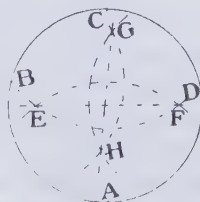


Fig. 10.

PROBLEM 11.

To bisect the angle formed by two converging lines AB, when the point of the angle is inaccessible.

Draw lines C and D parallel to A and B respectively (using the same radius for both) and at such a distance that they will intersect as at E. Bisect the angle CED by the line EF, which will bisect the angle contained in AB.

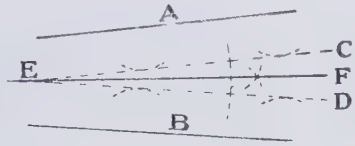


Fig. 11.

PROBLEM 12.

Through a given point A to draw a line which shall converge towards the same point as do two given lines B and C.

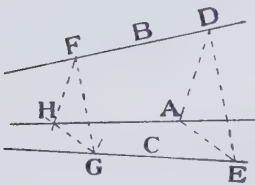


Fig. 12.

From A draw any two lines AD and AE join DE. At any convenient position draw a line FG parallel to DE, draw FH parallel to DA, and GH parallel to EA, then a line drawn through AH will converge towards the same point as do the lines B and C.

PROBLEM 13.

To draw a tangent to a given arc AC at a given point B.

From B with any radius less than BA or BC, describe arcs cutting AC in D and E. Join DE. From D and E as centres, and with radius BF, describe arcs G and H; then a line drawn just touching the arcs G and H will pass through the point B and be tangent to the arc AC.

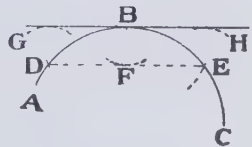


Fig. 13.

PROBLEM 14.

To divide a line AB into any given number of equal parts, say 6.

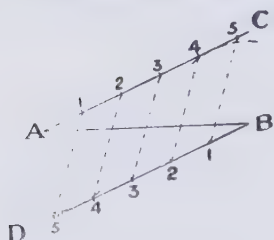


Fig. 14.

Draw AC at any angle and of any length ; from B draw BD parallel to AC. Set off from A along the line AC a number of equal divisions being one less than the number required on AB, and number them as shown. Set off along the line BD the same number of equal divisions using the same radius, and number

them from B as shown. Join number 5 on AC to number 1 on BD, 4 to 2, 3 to 3, and so on ; these lines will divide the line AB into the number of parts required.

PROBLEM 15.

To divide a given line AC proportionally to a given divided line AB

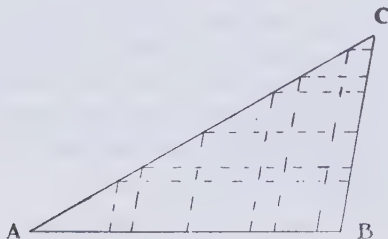


Fig. 15.

From A set off at any angle to AB the line AC to be divided. Join BC. From the divisions on AB draw lines parallel to BC meeting the line AC, AC will then be divided proportionally to AB.

Here it should be noticed that if one side of a triangle be divided into any number of parts and lines be drawn from these parallel to either side, the third side will be divided into the same proportion as the first side. In fig. 15, BC has been divided into the same proportion as the line AC by drawing lines from the points on AC parallel to the line AB.

PROBLEM 16.

To divide a portion AC of a line AB proportionally to the divisions on AB.

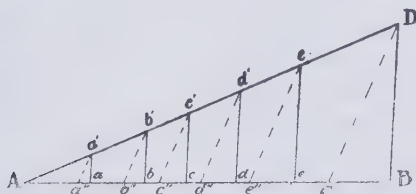


Fig. 16.

Let the points a, b, c, d, e , represent the divisions on AB. From A set off the line AD at any angle and length; join BD, and from the points a, b , &c., draw lines parallel to BD meeting the line AD in a', b' , &c., then from C draw a line to D, and from the points a', b' , &c., on AD draw lines parallel to CD, meeting the line AC in a'', b'' , &c., The line AC will now be divided into the same proportion as the line AB.

PROBLEM 17.

To set off a triangle of diameters and circumferences.

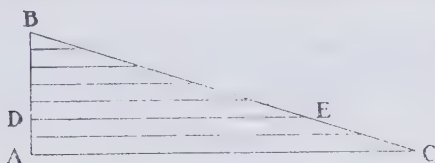


Fig. 17.

Set out a triangle ABC, having AB and AC in the proportion B 7 to 22, then the circumference for any diameter set off from on BA, such as BD, will be the line DE drawn parallel to AC.

This may be found useful to those making small pipes, and a convenient size is AB to be 14 inches and AC to be 44 inches, and if the angle at A be made a right angle, it may be used as a square, though for the purpose explained above it need not be made square.

PROBLEM 18.

To draw a line at right angles to a given line AB by means of a bevel, no compass being available.

Set off CD approximately at right angles to AB, and take the bevel of ACD; apply the bevel to CB, and set off CE. A line drawn from C evenly between D and E will be at right angles to AB.

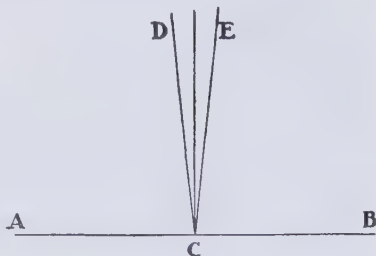


Fig. 18.

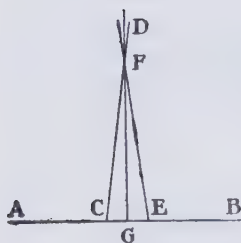
Another application of the bevel.

Fig. 19.

Set off the line CD to an open bevel position, and take the bevel of ACD; apply the bevel to EB so that one leg crosses the line CD as at F. Mark in the line FE, and measure for the centre of the portion CE at G. From G draw a line to F, which will be at right angles to the line AB.

These two figures are considerably exaggerated, most people being able to judge a right angle very nearly.

PROBLEM 19.

To construct a right angle by measurement.

It is very useful to know how to set out this figure, for it sometimes happens a square is required and there is not one handy, and may be there is not a bevel either. We are able to overcome the difficulty by applying the 47th proposition of Euclid, book 1 which states:—

“The square on the hypotenuse of a right-angled triangle equals the sum of the squares on the base and perpendicular.”

If, therefore, we take a right-angled triangle as having the base 8 inches, and the perpendicular 6 inches, it will be found the hypotenuse is 10 inches, for the square of 6 equals 36, and the square of 8 equals 64, which together equals 100, and the square root of 100 is 10. By this we are able to set out a right



Fig. 20.

angle as follows :—From a point C on the line AB, fig. 20, set off CD equal to 8 inches, and from C set off CE equal to 6 inches then from D set off DE equal to 10 inches, the angle ECD will be a right angle. Any lengths in the proportion of 6, 8 and 10 will apply, such as 3, 4 and 5, or 12, 16 and 20.

It may also be noted here that if the hypotenuse of a right-angled triangle be bisected, the point of bisection will be the centre of a circle which will pass through the three points of the triangle.

PROBLEM 20.

To construct a square on a given base AB.

Let AB be the given base. From A or B (in this instance B) with any radius less than BA, describe an arc EF, from E with the same radius cut the arc EF in G, and from G, with the same radius, cut the arc EF in H, from G and H, with the same radius, describe arcs intersecting at K. From B draw a line through K and produce it. From B, with radius BA, cut the

In practice, this method will be found more accurate than stepping around the circle from point to point, for by that method we would begin at D cutting the circle at F and G, then from F and G cut the circle at H and K, and from H or K cut the circle at E and join up as before,

but in this way we would have used at least four centres, whereas by the first method we have used only two, which tends to greater accuracy though theoretically they are equally correct.

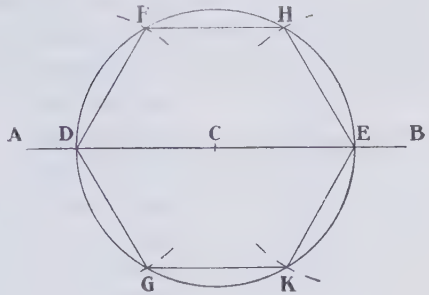


Fig. 23.

PROBLEM 23.

To find the centre of a circle which shall pass through three given points not being in the same straight line, as A, B, C.

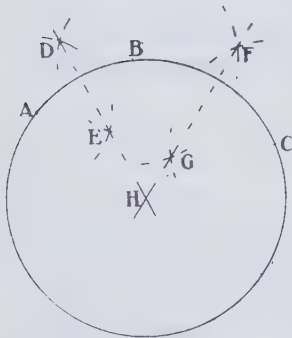


Fig. 24.

Join AB and BC. Bisect AB by DE produced, and bisect BC by FG produced; where these produced lines intersect at H will be the centre of a circle which shall pass through the given points ABC.

PROBLEM 24.

Within a given circle, to construct a regular polygon of any number of sides

Divide the diameter AB of the given circle into as many equal parts as there are to be sides to the polygon, in this instance five. From A and B, with radius AB, describe arcs intersecting at C; from C draw a line through the *second* division on AB,

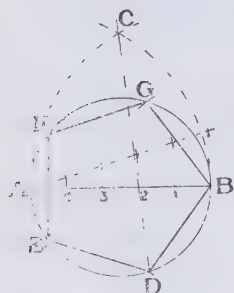


Fig. 25.

and produce it until it cuts the circle in D. Join BD, which will be one side of the polygon; from D, with radius BD, step out the figure in EFG, and join up the points DEFGB to complete the polygon.

In inscribing polygons by this method, the following rule must always be observed:—Divide the diameter into the same number of equal parts as there are to be sides to the figure, and draw the line from C through the *second* division.

Though this method is generally used for inscribed polygons it is known to be only approximate, but the inaccuracy is so slight that it is passed as practically correct.

PROBLEM 25.

To construct a regular polygon having the length of side given.

Let AB be the given side. Produce AB to C, and from B, with radius BA, describe the semi-circle AC, and divide it into the same number of equal parts as there are to be sides to the polygon, in this instance five. From B draw a line to the *second* division from C; this line will be the second side of the polygon. Bisect AB and B2 by lines intersecting at D, and from D, with radius DA, describe a circle. From A, with radius AB, cut the circle in E, and from E, with the same radius, cut the circle in F; join the points AEF2 by lines to complete the polygon.

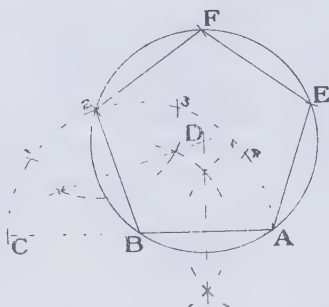


Fig. 26.

The following standard multipliers will be found useful for finding the radius of a circle to contain a polygon of a given

length of side. By their use it will only be necessary to multiply the length of side by the standard number for the number of sides, and the result will be the radius of the circle which shall contain the required polygon.

<i>Number of sides to the polygon.</i>		<i>Length of side to be multiplied by</i>	<i>Radius of Circle</i>
4	·7071
5	·8507
6	1·0000
7	1·152
8	1·306
9	1·462
10	1·618

ANOTHER METHOD.

*To describe any regular polygon, the length of side AB
being given.*

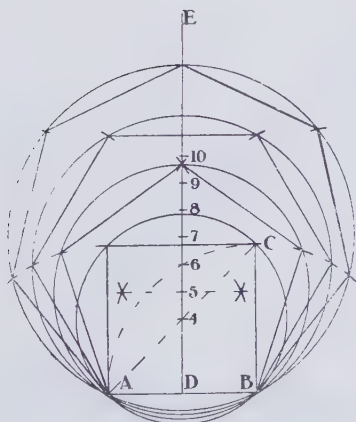


Fig. 27.

Let AB be the given side. From B as centre, and with radius BA, describe an arc AC. At B erect a perpendicular to AB, meeting the arc in C. Join AC. Bisect AB in D, and at D erect DE perpendicular to AB and of indefinite length, cutting the line AC in 4, and the arc AC in 6. Bisect 4 6 in 5, and from 6 with radius 6 5 step off on DE the points 7, 8, 9, 10, (and as many more as may be desired) numbering them as shown. These points

will be the centres of circles, which will contain polygons of a corresponding number of sides equal to AB.

This method, though approximate, is sufficiently accurate for most practical purposes.

PROBLEM 26.

To find the radius of an arc ABC by calculation, the length of the chord AC, and the height BD being given.

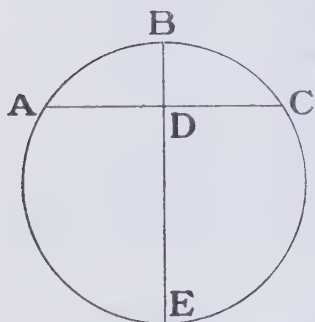


Fig. 28.

Rule :—Divide the square of half the chord by the height, then add the height and divide by 2.

Example :—Required the radius of an arc, the chord being 22 inches, and the height 6 inches.

Half of 22 equals 11; 11 squared equals 121, which divided by 6 equals $20\frac{1}{6}$, to which add the height, making $26\frac{1}{6}$, this divided by 2 gives the radius $13\frac{1}{12}$ inches.

The principal of this is as follows :—The rectangle on AD, DC is equal to the rectangle on BD, DE.

PROBLEM 27.

To take a bevel with a two foot rule.

Open the rule to the required bevel and make a note of the distance from A to B, the rule may now be closed and when that bevel is again required, set the rule so that the points AB are the same distance apart as before and the same bevel will be obtained. This will be found useful when away from the workshop, and no bevel tool is at hand for the purpose.

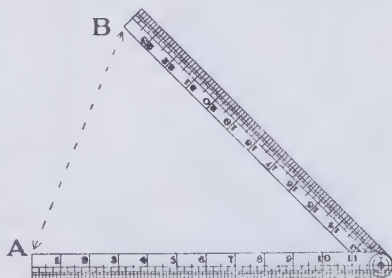


Fig. 29.

PROBLEM 28.

To describe an ellipse by means of a string or thread, the major and minor axes being given.

Draw the major and minor axes of the ellipse AB and CD at right angles to and bisecting each other in E. From C, with radius AE, describe arcs cutting AB in F and G; these points are called the *foci* of the ellipse. At C, F, and G insert or hold needle points, and around them tie a thread having no slackness, then remove the point C, and with a scribe held so that the thread is kept taut, trace the curve of the ellipse by moving the scribe along as shown in the figure.

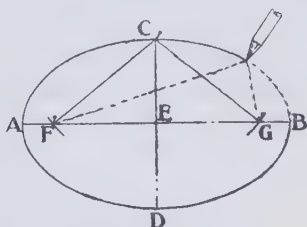


Fig. 30.

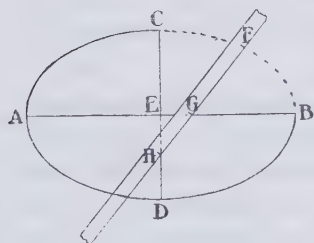
Another Method.

Fig. 31.

Having set out the major and minor axes in AB and CD bisecting each other in E, obt in a straight-edge, and on it set FG equal to CE, and from F set off FH equal to BE; then by keeping the point G always on the line AB, and the point H always on the line CD, the straight edge may be moved so that the point F will trace a true ellipse.

Another Method.

Set out the major and minor axes as in the previous figures, but produce them well beyond the length given. Obtain a piece of straight lath, and cut to a length equal to AE plus CE, and on it mark a point F distant from one end equal to AE, the other portion will of course equal CE. Now apply a square

to the figure in the position shown, having the angle at E, one leg of the square on the line AE, and the other leg on the line

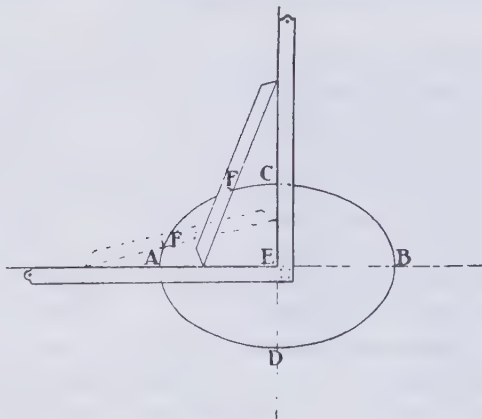


Fig. 32.

CE; then by applying the lath to the square and sliding it so that both ends are kept in contact with the square the point F will be made to trace a quarter of the ellipse; the other portions may be traced in the same manner.

It is well to remember a true ellipse cannot be described with compasses, and we would advise the reader not to resort to their use for this purpose, but would prefer the second method given here as being the handiest in the workshop, and where the size is small it may be traced with the two foot rule and be quite accurate.

PROBLEM 29.

The use of the stay in template making.

One of the most important figures in geometry is the triangle, more especially where questions of strength have to be considered. Its importance lies in the fact that it is not possible to have more than one triangle of the same length of sides, and

it is this property which makes it so essential to the staying of such work as the bridges, girders, roofs, etc., etc.

The veriest novice will readily grasp the fact that it is of great importance for templates to be so made that they cannot be altered in ordinary use, and to secure this rigidity we make a practice of using a stay when making our templates. Sometimes a template is self supporting by reason of its shape, independent of any stay as a separate detail, but where that is so

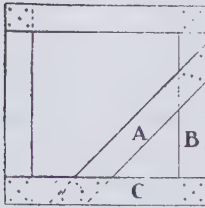


Fig. 33.

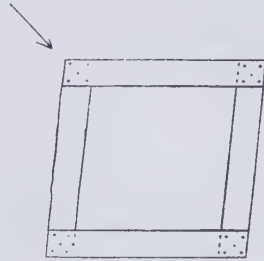


Fig. 34.

it will be found there is already one or more triangles in the template, still it is a matter which should be noticed by the workman, and if there is no triangle already forming a part of the template he should put one or more according to the size thus ensuring his work against alteration in handling.

In fig. 33 we show a simple application of the principle in a square template, one corner being tied by the stay A, thus forming, with the two adjacent sides a triangle ABC. The shape of such a template could not be altered without damaging it in some way, whereas without the stay the slightest blow may put it considerably out of true, thus rendering it useless, and even were the alteration but slight it may thereby escape the notice of the workman, and when he assembled his work he would wonder how it was his work did not prove as satisfactory as it should, and possibly end up by being condemned.

By referring to fig. 34 it will be seen how the template may be altered through having no stay.

PROBLEM 30.

To draw an arc through three given points ABC, not being in the same straight line, when the generating centre is inaccessible

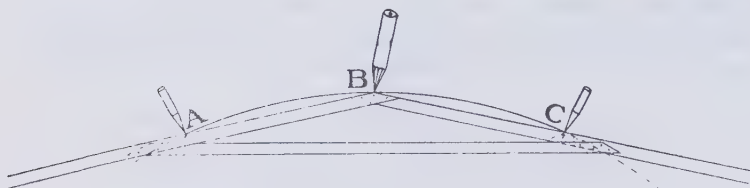


Fig. 35.

Let ABC be the three points. Obtain three battens, or template laths, and construct a template having one lath from B passing through A, another from B passing through C and the third as a stay to them. The laths should be straight, and should extend well beyond the points A and C. At A and C hold two pins firmly, and with a pencil or scriber at B move the template along keeping it close to the pins at A and C the while, and an arc may then be traced from A to C. Should it be required to extend the arc beyond A or C the template must be held in central position and on it mark the points A and C, then apply the template to the drawing having the point B on the template to the point C on the drawing, and the point A on the template fair to the curve already drawn; hold pins at points C and A on the template and proceed as before.

It does not matter whether the points ABC are equi-distant or not, the method here explained will always apply and the arc will be perfectly true, only one thing has to be borne in mind, namely: do not allow the point B to pass beyond the points A and C when moving the template along.

This method is particularly useful when developing cones of slight taper, such as the barrel plates of a boiler with in and out courses of plate, and is far more reliable than calculating the versed sine and drawing in the curve by means of a bent

lath, for be the eye ever so good it is not equal to true geometry or mechanical methods based on geometrical principles.

The principle on which this method is based is Euclid's 21st proposition in book 3, which states: "*The angles in the same segment of a circle are equal to one another.*" This is shown in fig. 36, where all the angles in the segment AB



Fig. 36.

are equal to one another, and from this it follows that if we assume the ends of the segment to be two given points, and a third be given at any position on the arc, the whole arc may be traced by treating the angle as a movable angle with its sides of indefinite length and at all times kept in contact with the points AB.

PROBLEM 31.

To divide a given circle into any number of proportionate areas by concentric circles.

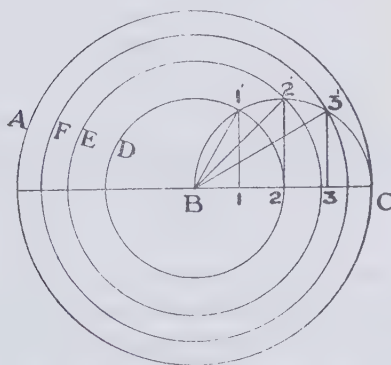


Fig. 37.

Let us suppose the given circle A has to be divided into four equal areas. On the radius BC describe a semi-circle, and divide BC into four equal parts in 1, 2, 3, and at each of these points

raise perpendiculars to meet the semi-circle in $1'$, $2'$, $3'$, From B with radii $B1'$, $B2'$, $B3'$, describe circles D, E, and F, the circle A will then be divided into four equal concentric areas.

This problem may be found useful when making ventilators which have to ventilate two separate compartments in proportion to their capacity; for instance, in fig. 38, a deck ventilator

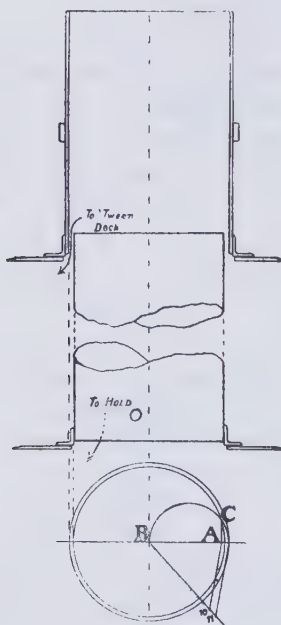


Fig. 38.

coaming is shown, in which is fitted another ventilator tube, the outer one is to ventilate between decks whilst the inner one is to ventilate the hold. We will suppose their relative capacities are as 1 to 10. Set out the coaming to the size given, and divide its radius into 11 equal parts, that is 10 for the inner, and 1 for the outer. At the first division from A raise a perpendicular to meet the semi-circle described on the radius; then BC will be the radius for the inner ventilator.

DIAMETERS AND CIRCUMFERENCES.

PROBLEM 32.

To find the circumferences from a given diameter.

Let C represent the circumference, and D the diameter, then by Rule 1. C equals $D \times 3.1416$.

Example :—Find the circumference of a circle, the diameter being 6ft. 4in.

$$\begin{array}{r}
 \text{C equals } 76 \text{ inches} \times 3.1416 \\
 3.1416 \\
 \quad 76 \\
 \hline
 18.8496 \\
 219.912 \\
 \hline
 \underline{\underline{238.7616}} \text{ inches, or } 19\text{ft. } 10\frac{3}{4} \text{ inches}
 \end{array}$$

Rule 2. C equals $D \times 355 \div 113$

Example :—Find the circumference of a circle, the diameter being 6ft. 4in.

$$\begin{array}{r}
 \text{C equals } 76 \times 355 \\
 \hline
 113 \\
 \\
 \begin{array}{r}
 355 \\
 76 \\
 \hline
 2130 \\
 2485 \\
 \hline
 113)26980(238.76 \text{ inches or } 19\text{ft. } 10\frac{3}{4} \text{ inches.} \\
 226 \\
 \hline
 438 \\
 339 \\
 \hline
 990 \\
 904 \\
 \hline
 860 \\
 791 \\
 \hline
 690 \\
 678 \\
 \hline
 12
 \end{array}
 \end{array}$$

Rule 3. C equals $D \times 22 \div 7$

Example:—Find the circumference of a circle, the diameter being 6ft. 4in.

$$C \text{ equals } \frac{76 \times 22}{7}$$

$$\begin{array}{r} 76 \\ \times 22 \\ \hline 152 \\ 152 \\ \hline 7)1672 \end{array}$$

$$238 + \frac{6}{7} \text{ inches or } 19\text{ft. } 10\frac{3}{4} \text{ inches.}$$

PROBLEM 33.

To find the diameter from a given circumference.

Let C represent the circumference, and D the diameter, then by Rule 1. D equals $C \times .31831$

Example:—Find the diameter of a circle, the circumference being 8ft. 3in.

$$D \text{ equals } 99 \text{ inches} \times .31831$$

$$\begin{array}{r} .31831 \\ \times 99 \\ \hline 2.86479 \\ 28.6479 \\ \hline \end{array}$$

$$\underline{\underline{31.51269 \text{ inches, or } 2\text{ft. } 7\frac{1}{2} \text{ inches.}}}$$

$$\underline{\text{Rule 2.}} \quad D \text{ equals } \frac{C}{3.1416}$$

$$\underline{\text{Rule 3.}} \quad D \text{ equals } \frac{C \times 113}{355}$$

$$\underline{\text{Rule 4.}} \quad D \text{ equals } \frac{C \times 7}{22}$$

In calculations for circumferences and diameters we would advise the use of Rule 1 in both cases, but which ever Rule the workman cares to adopt, it may be necessary to point out that in making tubes with circular lapped seams, the calculations

for inside and outside courses of plate should be made by the same rule.

In the making of plate tubes, the question of thickness of plate has to be considered in calculating our length of plate, for if we have the size given as the inside diameter, and we calculated from that without having regard to the thickness of plate, our tube would be too small when rolled up, and, on the other hand, if our given diameter was for the outside and we calculated from that, our tube would be too large; hence it must be clear the proper diameter is somewhere between these two. The line to be calculated from is that known as the neutral axis; this does not alter in length in ordinary bending, and its position is at the centre of the material; therefore, if we add half the thickness to the inside diameter at each end, or deduct half the thickness from the outside diameter at each end we have a new diameter from which to find the circumference. This is, of course, the same as adding the thickness to the inside size, or taking the thickness off the outside size, and resolves itself into the principle of working to the CENTRE OF THE THICKNESS OF THE IRON, and the developments in this work are based upon, and carried out according to that principle.

Calculations for circular seams.

In dealing with circular seams, whether butted with butt strap inside or outside, or both; or whether the seam is to be lapped, regard must be had to the difference in circumference as between the plates and butt straps, or inner and outer course of plate.

Where the two thicknesses are alike it is customary to make a difference of six times the thickness of the iron, but this is not sufficient. The proper amount is six and two-sevenths, and should the material be of considerable thickness the want of that two-sevenths will make a great difference to the quality and workmanlike finish on the job. If the thicknesses are not alike it will not do to make a difference of six and two-sevenths of either thickness, for if calculated from the lesser thickness

it will not give sufficient difference, whereas by calculating from the greater it will be too much. The proper method in such a case is to add together the two thicknesses and multiply by 3.1416, and add the result to the inner course, or take it off the outer, as the case may be.

It must be remembered in fitting up inner and outer courses of tube not to allow any burr or sheared edge to project, because to do so will be to have considerable difficulty in bringing the plates together. All burr should be carefully filed off, and the surfaces be clean before connecting up.

PROBLEM 34.

To find the circumference of an ellipse.

The usual method for finding the circumference of an ellipse is to add together the major and minor axes, dividing the result by 2 and multiply by 3.1416. This means treating half the added diameters as the diameter of a circle which shall equal the ellipse in circumference. This method is not said to be accurate, and while there appears to be no method yet devised which can be claimed as positively correct, a formula has been devised by the authors which will produce results much nearer than the usual method. This formula is as follows:—*To four times the hypotenuse of the right angle contained in a quarter of the ellipse, add .6264 of half the minor axis.*

Example:—What is the circumference of an ellipse, the major axis being 24 inches, and the minor axis 12 inches.?

The half of 24 squared equals 144

” ” ” 12 ” ” 36

180

then The square root of 180 is 13·4 the hypotenuse,
4 times 13·4 are 53·6, to which is to be added
·6264 of 6 which equals 3·7584.

Thus we have 53.6 plus 3.7584 as the circumference of the ellipse. Ans. 57.3584 inches.

The usual method applied to the given sizes would be as follows :

$$(24 \text{ plus } 12) \div 2 = 18 \text{ the new diameter.}$$

$$18 \times 3.1416 = 56.5488 \text{ inches circumference.}$$

If the reader will take the trouble to set out an ellipse to the sizes given above, and carefully measure the circumference, he will find it actually measures 57.9 inches. A comparison of the above results will show how much more accurate is the method here presented than the one usually used.

As an extreme example, let it be required to find the circumference of an ellipse, the major axis being 25 inches, and the minor axis 5 inches.

Half the major and minor axis will be 12.5 inches and 2.5 inches respectively.

Then : 12.5 squared plus 2.5 squared equals 162.5.

The square root of 162.5 equals 12.747.

(12.747×4) plus $.6264 \times 2.5$ equals 52.654.

Therefore 52.654 inches is the calculated circumference of the ellipse.

By the usual method we have $\frac{25 + 5}{2} = 15$, then 15×3.1416 equals 47.124 inches, the circumferences, but this is less than twice the major axis alone.

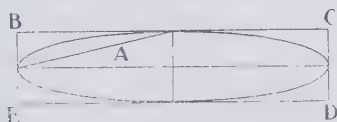


Fig. 39.

An ellipse carefully drawn to the sizes given proved to have a circumference of 52.375 inches, or .279 of an inch less than by the method we have set down. An examination of fig. 39 will show that the circumference of an ellipse must manifestly be greater than four times the line A, and less than the rectangle BCDE.

DEVELOPMENT OF PARALLEL TUBES.

Though tubes as such may be regarded as more or less alike, it will be found they vary considerably according to the manner in which they have to be made up, and the thickness of the plate of which they are made; for instance, there is a single plate tube, the tube with two or more plates in the circle, two or more plates in length, two or more plates in the circle and length, and in addition to these various forms of tube construction, the question of butt or lap joint has to be considered. In the process of marking out or developing, the matter of thickness plays an important part in tubes made up of tapering courses, for they are really conical tubes, and the circular seams have to be cambered in accordance with the taper produced by the thickness, the greater the thickness the greater the taper.

In tubes of slight thickness, such as donkey funnels and stokehold ventilators, it is not usual to make any allowance for the taper, because the camber would not be sufficient to make any noticeable difference in the finished tube, more especially if the plates are of a good length, but even with such light material, when the plate lengths are short the taper produced by the thickness should be taken into account, and the edge cambered to suit.

In addition to the consideration of tubes as separate items, there is the matter of rakes and other forms of ends and connections, and these may be of innumerable variety and still not depart from the form covered by the expression "parallel tube," for though a tube may be made up of a number of tapering lengths the entire tube will still be regarded as parallel when the taper is only due to the thickness of plate.

Having regard to the importance of dealing with the thickness of plate in calculations for circumference of tubes, we think it unnecessary to apologise for repeating the instruction previously given on the matter, therefore we mention here that in all calculations for the circumference of tubes when dealing

with their development, we CALCULATE FROM THE CENTRE OF THE THICKNESS.

Perhaps no better example of a butt jointed single plate tube could be given than the coaming for a ventilator, such as is found on the deck of merchant ships.

PROBLEM 35

To develop a butt jointed single plate ventilator coaming.

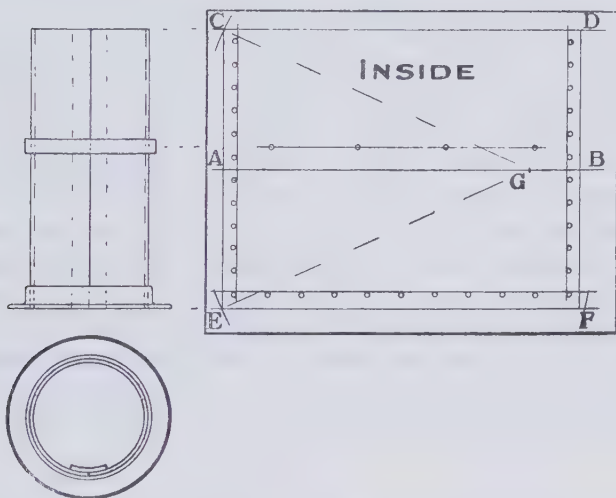


Fig. 40.

Let it be assumed the coaming has to be 1ft. 3ins. outside diameter, and 3ft. high, the plate to be $\frac{3}{8}$ in. thick. Take the thickness from the diameter and multiply by 3.1416, this will give the circumference as 45.9459 inches, or 3ft. $9\frac{5}{8}$ inches. The problem now resolves itself into the squaring off of a plate to the size of 3ft. $9\frac{5}{8}$ inches by 3ft. Through the centre of the plate strike a line AB, and on each side strike a line CD and EF 1ft. 6ins. from the line AB. At any point G near one end of the line AB make a small centre punch mark, and from G as centre, with a trammel, describe arcs near the opposite end of

the plate, cutting the lines CD and EF in C and E; join CE. Set off from C and E the points D and F equal to 3ft. $9\frac{1}{2}$ inches; join DF. The plate is now squared off to the required size in CDFE; CE and DF being the butt edges. The holes for the butt strap, bottom angle ring and cowl rest ring have now to be marked in, and here it may be mentioned, the holes near the edge of a plate are usually lined to the BACK of the mark, this is because they are easier and more accurately punched than were they lined through the centre. Strike lines distant from the butt lines equal to twice the diameter of the holes required, remembering that the diameter of rivet holes in practise is usually $\frac{1}{16}$ th of an inch more than the size as expressed, therefore, if the holes have to be $\frac{5}{16}$ in. they will really be $\frac{11}{16}$ if punched, and the distance from the edge of the plate to the BACK of the holes will consequently be $1\frac{3}{8}$ ins. Now strike the line for the holes to suit the bottom angle ring, regard being had to the depth of flange, and mark the holes to the pitch required after having marked the first hole at each end so that they shall also be fair to the butt holes as at C and D. Mark the first hole from E and F along the butt lines equal to half the pitch of the butt holes, and mark in the remaining holes as near to the pitch required as possible. Mark the holes for the cowl rest ring (usually about 4 and not taking the butt strap). The plate will now be ready for punching and shearing. The holes for the bottom ring should be punched from the opposite side and also the rest ring holes.

By planing the butt edges to a slight bevel, having the outer surface longer than the inside, will make a much better finish to the tube than were they sheared, for with sheared butts it is questionable as to which side of the plate is best for shearing in order to produce the best result. In the case of shearing from the inside surface, a slight bevel will be obtained which will be to the advantage of the butt, but a little depression will be made near the edge which will tend to keep the plates from closing tight to the butt strap. On the other hand, were the plate sheared from the outside surface the bevel would make an open or wide butt at the outside, whilst being close at the inside

Much will depend on the condition of the shear blades, and the manner in which the workman holds the plate in the process of shearing, and all things considered, it will be found that for a sheared butt it is best done from the inside surface.

The plate being punched and sheared, the butt strap will next engage our attention. This should be not less than six times the diameter of the holes in width, and the length will, of course, be the same as the length of the tube. Through the centre strike a line and set this fair to one butt edge of the plate and mark the holes; apply the strap in a similar manner to the other butt edge, keeping one end of the strap fair to the bottom in both cases; mark the holes. In lining the holes for the strap, they must be lined a little closer than shown by the marks, because as they are marked they are the same distance apart as they are from the butt edges on the plate, and this will be too much, they should be lined about $\frac{1}{8}$ th of an inch closer in this instance.

The butt holes in the plate should now be countersunk except those which take the bottom ring, and the plate may then be rolled up to shape. Before taking the plate from the rolls, get the butt strap hot and place it in the rolled plate, having previously raised the roll a little to allow for the extra thickness of the strap, then by passing the plate through the rolls again

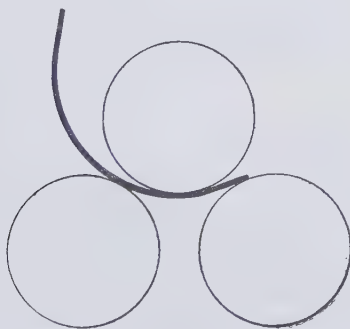


Fig. 41.

the set will be put in the butt strap to suit the tube. Take care to have the strap the proper side up when in the rolls.

In rolling up plates for tubes there is one drawback to perfect form being obtained, that is, the amount of flat surface between the bearing of the top roll against the plate and the bearing of the plate against the bottom rolls, as shown in fig. 41. Where the size of the tube is but little more than the size of top roll, a useful tool is a piece of shallow moulding placed under the edge of the plate as it approaches the bottom roll, see fig. 42, the



Fig. 42.

effect being to cause the plate to be bent nearer the edge, leaving a smaller surface to be "drawn up" on the slab, in fact, with most small tubes, there would be scarcely any flat left. With

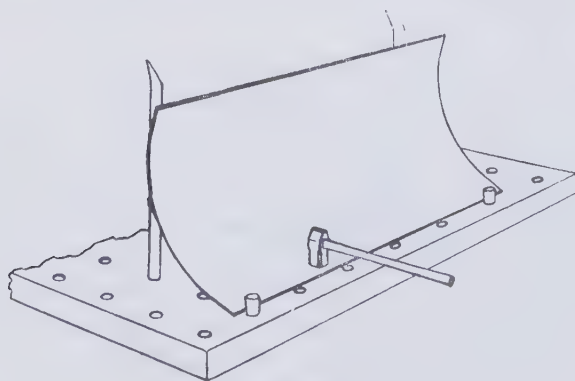


Fig 43.

tubes of large diameter and light plate the flat surface left by the rolls is usually "drawn up" on the slab by hammering, as shown in fig. 43 but it is obvious that with heavy plates, such as Boiler shells, hammering would be next to impossible, such plates are usually pressed to shape by hydraulic power, and in the most up-to-date boiler shops the whole plate is set to shape by this means, the press receiving the plate on edge.

PROBLEM 36.

To develop a lap jointed single plate ventilator coaming.

Let it be assumed the sizes have to be the same as in the previous problem. The squaring off of the plate will be done in exactly the same way as for a butt joint, but instead of the

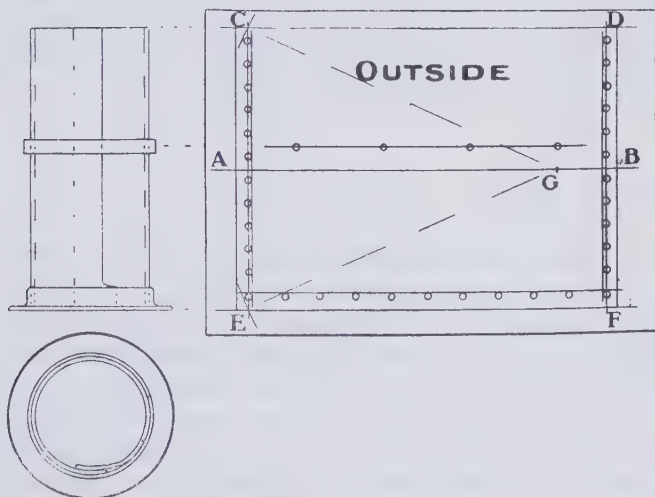


Fig. 44.

lines CE and DF representing the edges of the plate they will now be the lines for the centre of the holes for the seam. The holes having been marked in they should be lined to the BACK of the marks, and the development should represent the outside of the plate because it will mean less holes to be punched

from the other side. At the bottom it will be necessary to have a thinned corner on the outside in order to make a fair bearing surface to the angle ring; this is shown at F, fig. 44. The edge of the plate at DF should be sheared from the side marked, but the holes along the same edge will require to be punched from the other side. The proper side to draw the corner will be outside, as this will leave the faying surfaces of the seam level, and though the figure shows by dots a portion projecting at F, it is not usual in such a job to leave this on, but to shear straight through DF; it is only intended here to show the effect of thinning.

In laying out parallel tubes with more than one plate in the circle it will only be necessary to divide the circumference by the number of plates and proceed as explained in this and the preceding problem, care being taken to punch and shear from the proper side, and to note the corners to be thinned, these particulars are best marked on the plate in chalk, particularly if another workman has to complete the job.

PROBLEM 37.

To make a template for the plates of a main Funnel.

This problem is but a continuation of the subject of parallel tubes when considered in their entirety, and is intended not only as a demonstration of a tube made up of two or more plates in the circle and the length, but as an instruction on the making of main funnels in general. The most common form of construction is the longitudinal and circular lap seam pattern; it is simplest to make inasmuch as there are no butt straps or bands to consider with the exception of the moulding ring for the top, but in the marking out of the template for the plates the circular lap seam brings into the problem the difference in circumference as between the inside and outside plates at the circular seams. This difference will have to be allowed for, the amount for each plate depending on the number of

plates in the circle, and though each length of tube is, strictly speaking, a frustum of a cone, the amount of taper is so small that it would be almost impossible to set out the camber in each separate plate; it is consequently neglected altogether. Each plate is squared up to the greatest width, and at one end the width is made narrower according to the amount required to make up in the total plates the correct difference in circumference between the inner and outer courses.

Fig. 45 represents a main funnel 45 feet long by 7 feet diameter inside the bottom, the plates to be $\frac{1}{4}$ inch thick. The development of the bonnet will be dealt with later on.

The figure is shown as having five plates in the length, and six plates in the circle, with the position of the bonnet ring on the second course of plates. We will take the plate marked A as our template, the inside of each course at the bottom being the same diameter as the bottom of the funnel. On calculating the circumference it will be found the bottom is 22ft. 0 $\frac{1}{8}$ in. measured at the centre of the iron; this divided by six (the number of plates in the circle) gives 3ft. 8 $\frac{1}{2}$ ins. full as the width of plate at the bottom, centre to centre of holes. The thickness of plate being

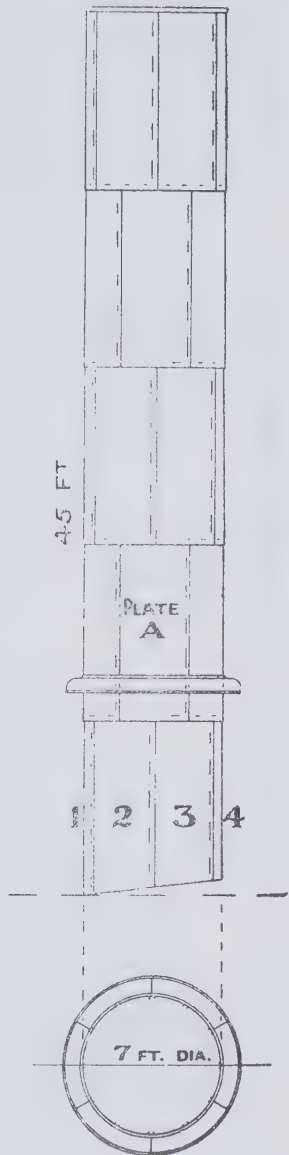


Fig. 45.

$\frac{1}{4}$ in., and this multiplied by 6.2832, which is twice 3.1416 gives $1\frac{9}{16}$ ins. as the difference between the two circumferences, and this difference divided by six and deducted from 3ft. 8 $\frac{1}{8}$ in. full will give 3ft. 7 $\frac{7}{8}$ ins. as the width of the plate at the top, centre to centre of holes. The length of plate being 9ft. centre to centre of holes, we now have all the particulars necessary for making the template.

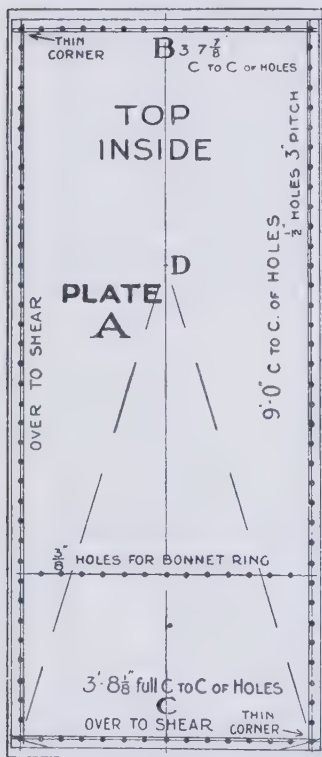


Fig. 46.

bonnet ring, these are usually $\frac{3}{8}$ in. diameter, mark on the plate the corners to be thinned, and which edges have to be sheared from the other side. The template will now be ready for punching and shearing.

Square off the plate (fig. 46) to the full width at both ends in order that the arcs described from D shall cut the side lines exactly opposite each other, and when joined the line shall be at right angles to the centre line. Reduce one end to the required width, and pitch off the holes at both ends with a dividers, taking care to have a hole on the centre line, as this hole will be a joint hole for the next course of plates. Mark off the sides to the pitch shown on the drawing—(usually 3 inches). In most workshops a strip of iron is kept, having holes suitable for this purpose and saves dividing off along the side seams, the seam holes being marked from the strip. Strike lines to the back of the marks and line in the proper lap. At the position shown on the drawing, line in the holes for the

The whole of the plates may now be marked from the template, but the top course will not require so many holes for the moulding ring as are put in for the seam, about five in each plate will be found sufficient. The bottom, having to be cut off at a bevel will be left blank, but it should be noticed that the top and bottom courses of plates will have to be thinned at the outside seam edge at both ends instead of at opposite corners as is the case with the intermediate plates.

We will assume all the plates except the bottom course are now marked off. The matter which will now engage our attention will be to mark in the rake, and this we desire to do, plate by plate, instead of the usual method of laying the whole of the course of plates out and marking in the line through them all at one time; this method not only takes more time to do, but means handling the plates twice over, whereas by the method we explain they may be marked at the same time as the holes.

Before dealing with the plate by plate method of marking a rake line, we will show the usual way to mark out the development of a tube cut off at a bevel, this being exactly what a rake line means.

PROBLEM 38.

To develop a tube cut off at a bevel.

Let ABCD, fig. 47, represent the elevation of the tube, and E the plan. Draw a diameter $a d$ parallel to AD, and divide

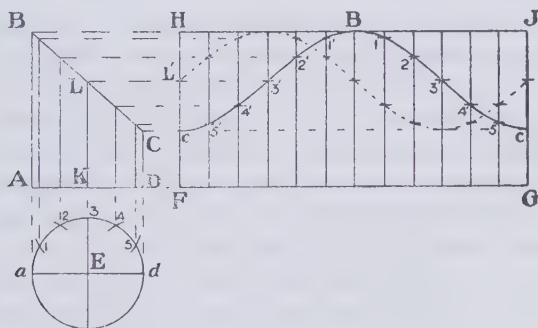


Fig. 47.

the sem-circle into six equal parts as $a, 1, 2, 3, 4, 5, d$; project these points to the line BC by lines drawn parrallel to AB. Draw a line FG in a position continuous with AD, and equal to the circumference of the tube. Erect FH, and GJ perpendicular to FG and equal to AB; join HJ. Divide FG and HJ into 12 equal parts, and join them as shown. From the points on BC project lines parallel to AG in $c, 5', 4', 3', 2', 1'$. Draw a fair curve through these points to B to complete the development. The problem, so far, has been done to suit a tube with the butt at DC; should the butt be required on the line KL, the development would be in the position shown by the dotted curve commencing at L', and this will be found the best for such tubes as donkey funnels, or in fact for most tubes which have to be connected in what is termed an elbow.

PROBLEM 39.

To mark in the rake line of a tube cut off at a bevel.

PLATE BY PLATE METHOD.

In order to demonstrate this method clearly we will direct the reader's attention to fig. 48, in which C represents a development obtained by projection from the circles a and b in the plans to the lines EK in the elevations, and from these points on EK to the development C. But the development C has no relation to either of the tubes A or B so far as diameter and circumference are concerned; what then is it that enables us to project a correct rake development on a given width of plate as hh ? There is only one particular common to both the tubes A and B; that is the height of rake as shown by the lines DE. With this known, it will be shown it is unnecessary to go to the trouble of describing circles and projecting lines to elevations, and then from them to the development, because the governing factor is contained in that one quantity, namely, the height of the rake.

An examination of the figure will show that while the lines DE are equal, and represent the height of rake in both tubes, the lines HJ are not equal, neither are the lines EK, yet if semi-circles be described on DE and EK in M and L, and divided into six equal parts, lines drawn from these points at right angles to DE and EK respectively will meet at the corresponding points on EK projected from *a* and *b*, hence it follows that as DEK is a triangle the line DE is divided into the same proportion as the lines DK and EK (see Problem 15, fig. 15), therefore, if the length of DE be known, and the proportion into which it is

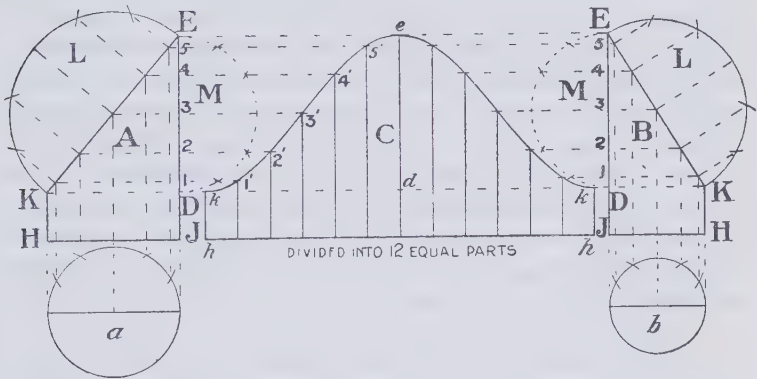


Fig. 48.

divided, the development may be set out without making use of either a plan or elevation of the tube which has to be developed, and in order to standardise this proportion we determine on TWELVE divisions for the development and SIX for the height of rake. The twelve divisions will of course be equal to each other, but not so with the six on the rake line; these have to be determined from a circle. To find this proportion we will assume DE to equal 12 inches, the radius of M will be 6 inches. The semi-circle M being divided into 6 equal parts using its own radius for the purpose, lines may be projected to DE from these points on the semi-circle which shall cut the line DE in 1, 2, 3, 4, 5, then the distance from D to 2 will be found to be

one quarter of DE, D 3 will be half of DE, D 4 will be three quarters of DE, leaving D 1 and D 5 to be determined by calculation, but as D 1 is equal to E 5 there will be only one division to calculate. By the 47th proposition of Euclid, this division has been calculated to be $\cdot 8039$ of an inch, or say $\frac{1}{126}$ ths of an inch when the rake is 12 inches. As $\frac{1}{126}$ ths expressed in decimals is $\cdot 8125$, it will be seen the standard we give for the first division is but $\cdot 0086$, or $\frac{1}{116}$ th of an inch out of 12 inches rake. By this method we have DE divided "proportionally for projection."

In setting out the development C having the rake $d e$ to equal 12 inches, strike the line hh and divide it into 12 equal parts, each part will be in inches what hh is in feet; thus if hh is 16ft. each division on hh will be 16 inches. At each division raise perpendiculars to hh , cut off hk equal to HK, and join the points kk , then from the line kk make the first division 1' equal to $\frac{1}{126}$ ins., 2' 3ins., 3' 6ins., 4' 9ins., 5' 11 $\frac{3}{8}$ ins., and e 12ins., draw a fair curve through these points to complete the development of the rake line. Had the rake $d e$ been given as 6ins. each of the divisions would be in the proportion of 6 to 12; thus 1' would be $\frac{1}{2}$ in., 2' 1 $\frac{1}{2}$ ins., 3' 3ins., 4' 4 $\frac{1}{2}$ ins., 5' 5 $\frac{1}{2}$ ins., and e 6ins., and in like manner for any height of rake.

Having shown that kk may represent any circumference it will be seen we need but a small diagram by which to set out

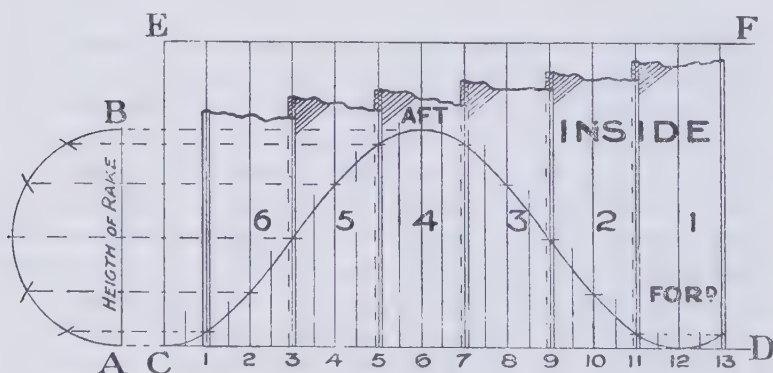


Fig. 49.

the rake line for the main funnel (fig. 45), and in order that it may be done plate by plate we make a drawing of the rake line on a small scale, and divide it up into the divisions corresponding to the number of plates, and from the drawing take off the heights of the lines for each plate as it is dealt with. This is shown in fig. 49, where the line CD has been drawn, and on it are set off a number of equal divisions numbered up to 13 from C. EF has been drawn parallel to CD, and the line CE has been set off square to CD. If C 12 be made 2ft., each of the numbered divisions will be 2ins., and if we take the height of rake to be 9ins. the height of 1 and 11 will be $\frac{9}{16}$ in. full, 2 and 10 will be $2\frac{1}{4}$ ins., 3 and 9 will be $4\frac{1}{2}$ ins., 4 and 8 will be $6\frac{3}{4}$ ins., 5 and 7 will be $8\frac{7}{8}$ ins. bare, and 6 will be 9ins. from the line CD. As the fig. 45 shows the centre of plate 1 as the longest part of the funnel this must be at the point C, or 12, we have therefore extended the divisions to 13, making the height of 13 the same as 11.

After drawing in the curve through the points obtained by measurement, note that the lines 1, 3, 5, 7, 9, 11 and 13 represent the centre line through the seam holes of the plates. At the centre of each of the divisions already set out draw a line cutting the rake line, as shown in the fig., this will give five lines for each plate—the two seams, and three in between.

Let us now proceed to set out the curve on plate 1. Mark off the plate from the template, fig. 46, and at the bottom, instead of marking all the holes, only mark the centre hole; the centre of this hole will be the longest part of the funnel. Strike a line joining the end holes of the side seams, and divide it into 4 equal parts (it will already be divided into 2 by the centre hole), and at each point strike a line about a foot long parallel to the centre line, then take off the heights of the lines from the small drawing on to those on the plate, and with a lath bent fair to these points the curve for that plate will be obtained.

The lines and curves for each of the plates may be taken off in a similar manner, the whole of the drawing not taking up more space than about 2ft. 4ins. by 1ft., the complete rake

in the funnel will be perfectly accurate, and all the plates will have been marked off without any laying out or handling the second time.

Fig. 50 shows a rake line CGD, the height of G being 12 inches, but as the number of plates is five, the division lines are cleaned off and CD, FE re-divided into 20 equal parts,—(four

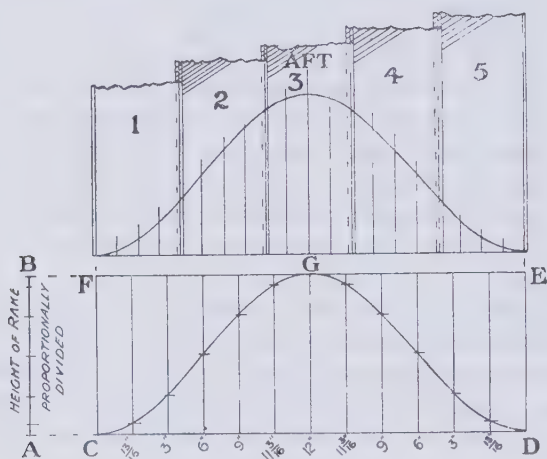


Fig. 50.

for each plate)—the figure then appears as shown immediately above from which the heights for each plate may be taken. AB shows the rake height proportionally divided, and is the same as the proportions on the line AB, fig. 49, and AD, fig. 47.

The corners of funnel plates are usually thinned on the slab during the time they are being drawn up after rolling; the plates seldom being heated for this.

When marking off the top length of plates it will be necessary to line through the centre of the top holes for shearing in order to have the dead length of funnel correct, the holes for the moulding ring being lined in half the width of the ring from this line.

PROBLEM 40.

Funnels fitted with bands.

Main funnels fitted with bands are always made parallel, therefore the template for the plates will present no difficulty, but what must be taken into account is the number of bands and the width from centre to centre of holes, because it will be necessary to deduct this from the total length before dividing by the number of plate lengths in the funnel.

Suppose the funnel has to be 45ft. total length, and there are to be five courses of plate fitted with bands at four seams; these bands are, of course, butt straps, and they are generally about 5 inches wide by $\frac{3}{8}$ in. thickness. The holes in such a band would be $2\frac{1}{2}$ ins. apart centre to centre lengthwise of the funnel, and as there are four bands to be fitted it will mean a reduction of 4 times $2\frac{1}{2}$ ins. for the total length of plates, so that instead of taking a length of 45ft. we have to take 44ft. 2ins. as the length, and this divided by five will give the length of each plate as 8ft. 10ins. centre to centre of holes.

In the case of funnels fitted with bowling or expansion bands the allowance will be a little more because they are usually wider than flat bands, and the plates are never allowed to extend beyond the flat portion, as shown in fig. 51

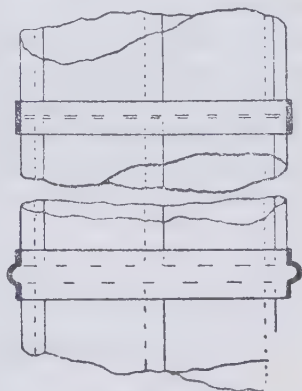


Fig. 51.

Flat bands are mostly welded, but not so the expansion band; these are butted, and while it would be an easy matter to set out the holes in a flat band and punch them before rolling up it is not wise to do this, as the material being weakened by the holes will cause the iron to bend in a series of flat places from hole to hole. The best way is to calculate the circum-

ference and cut the bar off to that length, plus an allowance for welding; scarf the ends, and roll up to a circle. The band should then be welded.

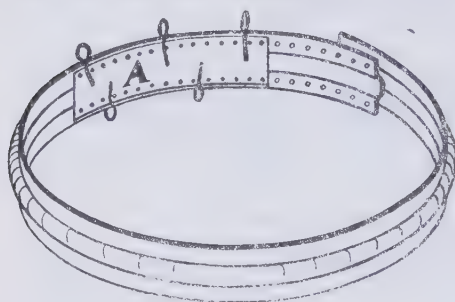


Fig. 52.

To mark off the holes make a strip template from the end of the plate and of the same thickness, having two rows of holes properly set to represent two plates when the strip is bent up and applied to the band for marking ;

this method is shown in fig. 52, the strip A being applied to an expansion band, the butt of which will be cut after the holes are marked. The same process applies to the top moulding ring because if the holes were drilled before rolling it is more than likely the iron would break at the holes when rolling up.

Fit. 53 shows the effect produced on an expansion ring in the process of rolling, and though the "splaying" is less than illustrated here it will be found the strip template does not lay close to the edges of the bar when marking off, but the amount will be very slight in rings of large diameter, and in most cases may be neglected. The only way to avoid this "splaying" is to bend the ring hot around another ring of suitable diameter and depth when any distortion may be corrected with a hammer.



Fig. 53.

PROBLEM 41.

To lay out the template for an in and out plated boiler shell.

This class of work demands the consideration of camber in the edge of the template produced by the thickness of plate giving a slight conical shape to the tube, the amount of taper being equal to twice the thickness of plate.

Let it be required^{to} set out the template for a tube ABCD to be made in two plates to the circle. Fig. 54.

Strike a line across the plate about the middle of the length and make $a b$ equal to AB; from a with radius AD (measured from centre to centre of the iron) describe arcs at d and f ; from b with radius BC, also measured from centre to centre of the

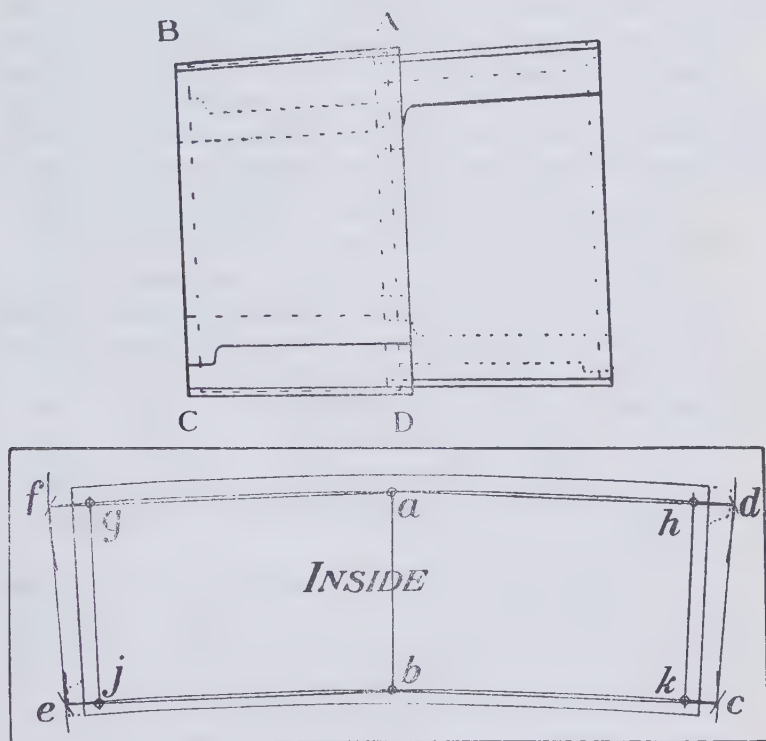


Fig. 54.

iron, describe arcs at c and e ; from a with radius AC describe arcs at c and e intersecting those already described from b ; from b with the same radius describe arcs at d and f intersecting those already described from a . Join $d c$ and $f e$, $f e b a$ and $a b c d$ will each equal ABCD at the centre of the iron and seams. By applying Prob. 30, fig. 35, the proper camber may be drawn

through the points $f a d$, and with the same batten the camber may be drawn through the points $e b c$.

Now calculate the circumference of AD at the centre of the iron, and set out one quarter on each side of a , measured **ALONG THE CURVE**, in g and h . On each side of b set out along the curve j and k equal to one quarter of the circumference of BC at the centre of the iron; then the curves $g a h$ and $j b k$, and the straight lines $g j$ and $h k$ will be the lines for the centres of the holes. Pitch off the holes with a dividers, taking care to have one at a and b as these will be the joint holes for the adjoining course of plate, mark in the required lap, and note the corners to be thinned. The template may now be punched or drilled, the latter for preference, especially with boiler work.

The template being complete any number of plates may be marked from it, and when fitted together all holes will be fair.

If the holes are to be punched, the template should be applied to the plate and the holes along $g a h$ and $g j$ marked off, and the edges of the lap at $j b k$ and $k h$ marked for shearing leaving the remainder to be done from the other side by turning the template and the plate over and applying the template to that already done.

It will be noticed the thinned corner of a plate almost invariably occurs at the corner where the adjoining holes are punched from opposite sides.

For marking the camber in a plate when the radius is too great to permit the use of a trammel the above method will be found far easier and more accurate than calculating the versed sine and using a lath to judge the curve, because this method is positively correct, and only requires ordinary care in marking out.

PROBLEM 42.

To mark out an elbow connection between two parallel tubes.

A and B, fig. 55, represent two tubes connected at the elbow or rake line CD; EF being at right angles to the centre of A,

and GH at right angles to the centre of B. EF and GH have been divided proportionally for projection (Prob. 39. fig. 48), and from the points obtained lines have been drawn parallel to the centre line of A and B respectively, meeting on the line CD. The lines LM and NO have been drawn at right angles to FD,

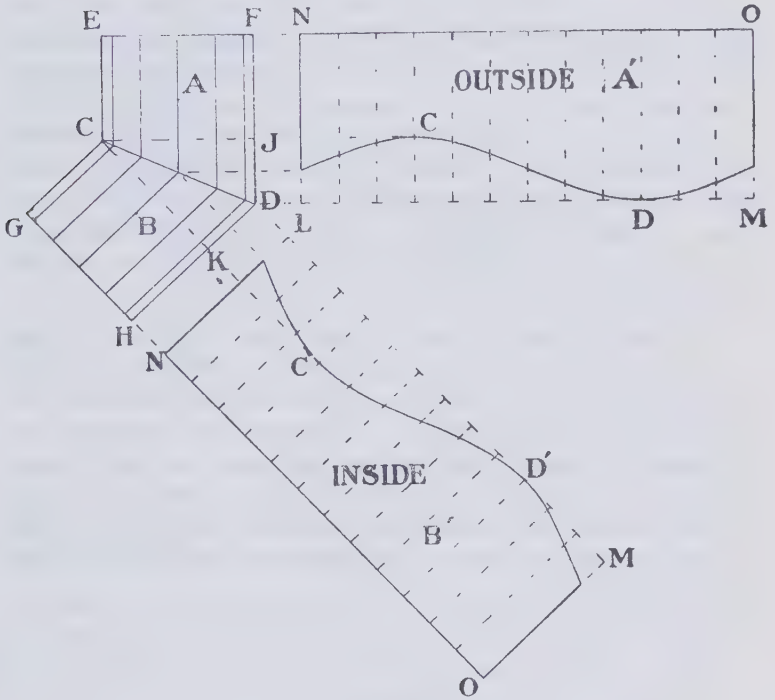


Fig. 55.

and HD, and are equal to the circumference of the tubes; NL and OM being at right angles to LM. LM and NO have been divided into 12 equal parts and connected, and the points on CD have been projected to these division lines by lines drawn parallel to LM, producing points through which have been drawn fair curves giving the developed elbow.

Thus far the figure has been set out by the usual method,

but by applying the method known in Prob. 39, fig. 48, the curves may be obtained in the following manner. From F set off FJ equal to EC and set off HK equal to GC; then by dividing the portions JD and KD proportionally for projection the heights for the rake lines will be found, and may be set out from the lines LM.

The best place to have the seam is at that part where there will be no flanging when fitting the tubes together, and the seams should also be opposite each other. To fit the tubes in this manner the greatest height of rake should be at the third division from one end as D' from M, and the figure shows A' representing the outside while B' shows the inside. In tubes of small diameter the points through which the curves have been drawn may be taken as the centre of holes, and when the tubes are fitted together the holes will meet in the same manner as the lines of A and B do on CD.

In detailing this problem, no account has been taken of thickness of plate, and with thin material such as sheet iron it would be quite satisfactory, but when material has to be used which necessitates a consideration of the thickness in calculating the difference in circumferences between the inner and outer courses of plate, this difference must be taken into account in laying out the elbow, because there will be a difference in the heights of rake for the two tubes, an explanation of which will be found in the next problem.

PROBLEM 43.

To find the difference in the rake heights of a lap jointed elbow.

AB and BC, fig. 56, are the centre lines of two parallel tubes; ABC being the angle they have to assume when finished. Bisect the angle ABC by the line DE; this will be the rake line. Draw FG at right angles to AB, and make AF and AG each equal to half the diameter of the outer course of tube, measured at the

centre of the thickness. From F and G draw lines parallel to

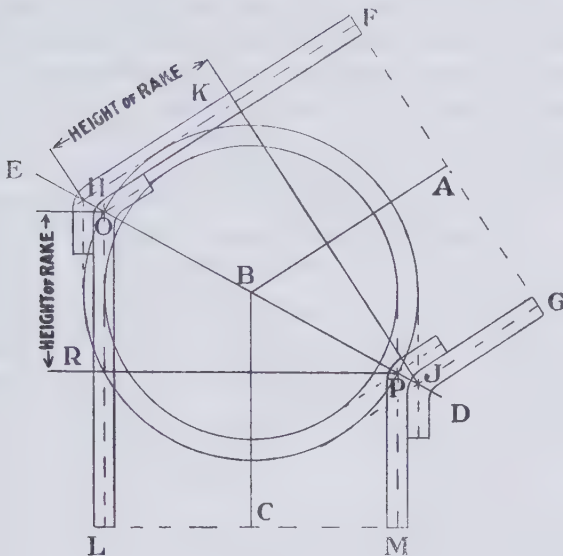


Fig. 56.

AB till they meet the rake line DE in H and J. Draw JK parallel to GF, then KH will be the height of rake for the outer course.

Draw LM at right angles to BC, and on each side of C set off L and M equal to half the diameter of the inner course of plate measured at the centre of the thickness. From L and M draw lines parallel to CB till they meet the rake line DE in O and P. Draw PR parallel to ML; then RO will be the height of rake for the inner course of plate.

By finding the rake heights the developments may be set out in the manner shown in Prob. 39, fig. 48, and in flanging the elbow the inside course should be done first, and the throat of the outer course next leaving the part at H to be closed over the part at O when the tubes are put together. If the material is of light weight, the part at H may be closed over after the tubes are connected, but if the material is somewhat heavy it

may be flanged, and the seams let go to connect up the elbow, and when finished it will be found to be a lock joint. The best place to have the side seam is at the line AB for the outer tube, and at the opposite side of BC for the inner tube, then there will be no drawing of the seam in flanging. The circles described in the figure represent the centre of thickness.

PROBLEM 44.

To develop the branch connection of two parallel tubes of equal diameter.

Draw a line AB, fig. 57, and from a convenient point C draw a line CD at the required angle for the branch. At C describe

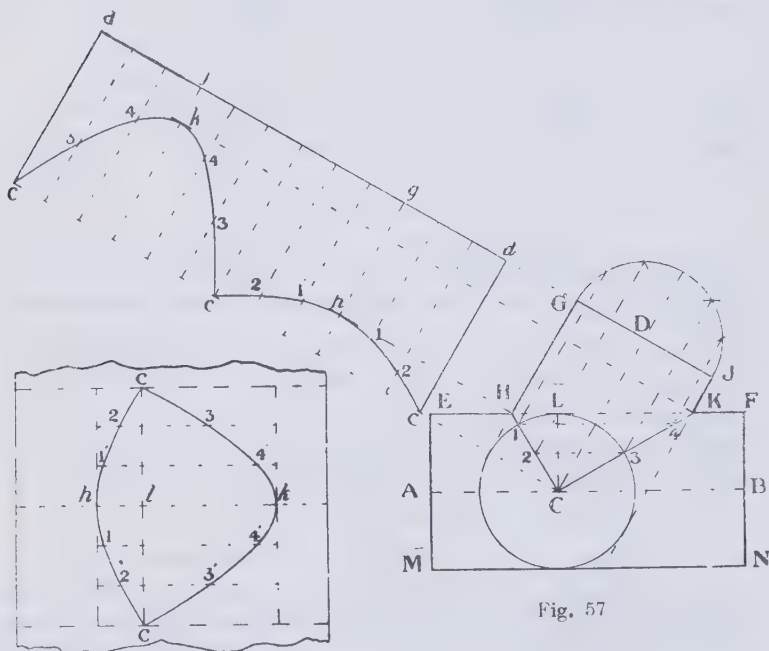


Fig. 58.

Fig. 57

a circle equal in diameter to the tubes. Draw EF tangent to the circle and parallel to AB, and GH and JK tangent to the

circle and parallel to CD. Join HC and KC, then HCK will be a right angle whatever the angle DCB may be. Draw GJ at right angles to CD, and divide it proportionally for projection, (Prob. 39, fig. 48). From the points on GJ draw lines parallel to CD, meeting HC in 1 and 2; and meeting CK in 3 and 4. Draw $d d$ in line with and equal to the circumference of GJ; draw $d c$ each equal to DC and parallel to it; join $c c$. Divide $d d$ and $c c$ into 12 equal parts, and join them as shown, then commencing at C project the points C, 2, 1, H to the development in c , 2', 1', h , parallel to $c c$. Project the points 3', 4', k , from 3, 4, K, in a similar manner. Through these points draw fair curves to complete the development.

This development may be easily done by Prob. 39, for the difference between GH and DC will be half a rake height from which the curve $c h c$ may be drawn, and similarly the difference between JK and DC will be half a rake height from which the curve $c k c$ may be drawn.

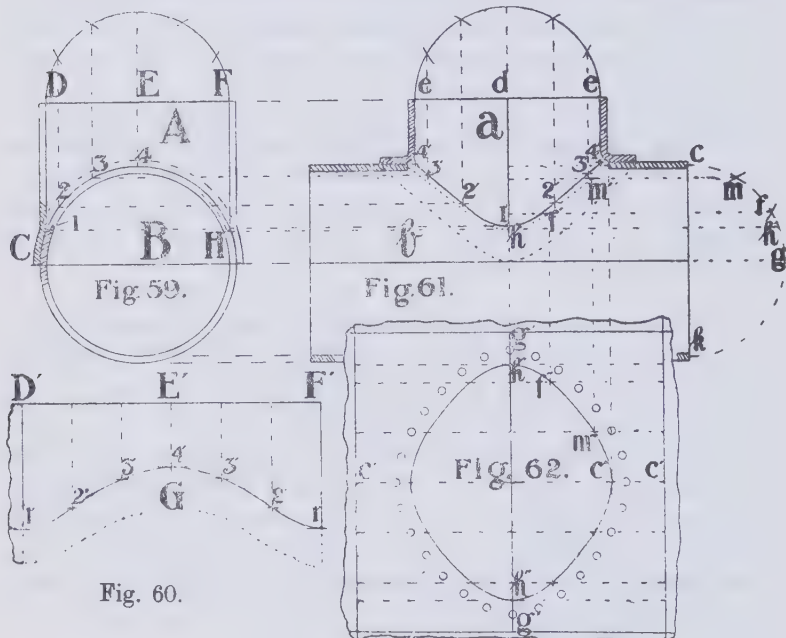
To develop the hole in the tube AB, draw CL at right angles to EF, then LH will be half a rake height, and LK the other half rake height. Draw $c c$, fig. 58, equal to half the circumference of the tube AB; from the centre of $c c$ set off at right angles, $l h$ and $l k$ equal to LH and LK. Through h and k draw lines parallel to $c c$ and of the same length; divide these lines into six equal parts, and connect them as shown. Set off the points 1', 2', 3', 4', from the line $c c$ corresponding to the distances they are from CL in fig. 57, and through these points draw fair curves to complete the development. The best position for the seams will be at DC and MN.

As with fig. 55, this development will serve well for thin material, but with heavier plate there will be the thickness to contend with, and this will produce a somewhat different shape to the connection, or else it will mean a considerable amount of set out to the branch tube in order to fit on the main, this set out being greatest at the point C, and diminishing as the points H and K are approached; this will be clearly seen in the next problem.

PROBLEM 45.

To develop a T branch connection formed by tubes of equal diameter.

A and B, fig. 59, is an end view of the proposed connection showing the set out of the plate at C. This set out is due to the tubes being equal in diameter and the plate of sufficient thickness to require considering when determining the position where the



root or heel of the flange of A shall engage with the tube B, and to find this position it is necessary to work to the *inner* surface of A and the *outer* surface of B, because it is the inner surface of A which has to be centre marked for flanging, and it is this flange line which determines the shape of the hole in the tube B.

Having set out the sectional view of A and B, divide DF (the inner diameter of A) proportionally for projection (Problem 39, fig. 48), and from the points obtained draw lines meeting the

outer surface of B in 2, 3, 4: the point 1 is where the inside line from D engages with the outside of B. Fig. 60 shows a half template of the tube A, and is laid out in the following manner. Draw a line D'F' equal to half the circumference of A (calculated from the centre of the iron), and divide it into six equal parts. From the points on D'T' draw lines at right angles to D'F', and cut them off corresponding to those on A in 1', 2', 3', 4', and through these points draw a fair curve which will be the line for the root of the flange. Add on the flange required, taking care to allow extra material at G on account of the great amount of stretching to be done at that part.

If it is intended to have a butt at F' 1', a little extra flange should be allowed on as shown by dots, and when the flanging is complete this extra may be jumped to bring a fair butt on the flange where it will have spread open.

To obtain the development of the hole in the tube B, set out a side view of the tubes in *a* and *b*, fig. 61, having the line *ee* continuous with DF, fig. 59. The size of the hole will be governed by the turn of the flange on the tube *a*, as will be seen where the thicknesses are shown in section. Divide *ee* proportionally for projection, and from the points obtained draw lines well into the tube *b*. Project the points 1, 2, 3, 4, fig. 59, by lines drawn parallel to *ee* until they cut the lines drawn from *ee* in 1', 2', 3', 4', and through these points draw a fair curve, which will be a side view of the position of the root of the flange. Project the point H, fig. 59 (representing the centre of the thickness at the edge of the hole in B) to the centre line of *a* in *h*, and from *h* draw a line to the centre of the section of *b*; this will show the side view of the hole in the tube *b*, shown dotted. Describe a semi-circle *cgk* at the centre of the thickness, and with the same radius from *c* and *g* describe the arcs *f* and *m*; project the points *f* and *m* parallel to the centre of the tube *b* till they meet the line *dh* after cutting the dotted line in *f'*, *m'*. Project *h* to the semi-circle in *h'*.

Draw the lines *g'g'*, *c'c'*, fig. 62, at right angles to each other, and on each side of *c'c'* set off *g'* equal to one quarter of the

circumference of the tube b . Divide $g'g'$ into six equal parts, and through these points draw lines parallel to $c'c'$ and cut them off in c'' , m'' , f'' , equal to their corresponding lengths from dh in fig. 61. From g' set off h'' equal to gh' measured along the semi-circle. Draw a fair curve through the points h'' , f'' , m'' , c'' , and treat the other portions of the figure similarly to complete the shape of the hole.

The rivet holes may now be marked and drilled, and when the plate is rolled up the flanged tube A may be applied to it to mark the holes on the flange. Better work would be produced if the holes in the tube B were drilled after the plate is rolled up, because all distortion of holes resulting from rolling after drilling would be avoided. If the butt of the tube A has to be on the line dh , there will of course not be a hole on the line $g'g'$, though the fig. 62 shows such; they should be pitched according to the width of strap to be fitted, avoiding the butt line.

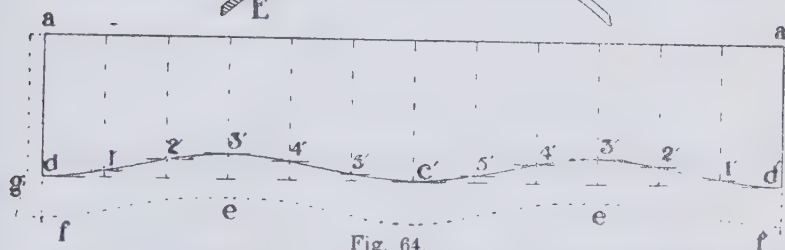
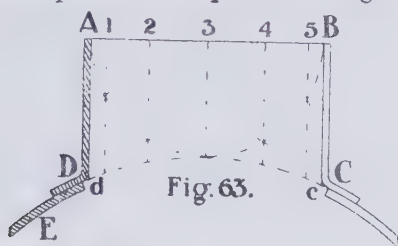
When flanging the tube A it should be commenced at C, fig. 59, and worked up to about the point 3, then do the other side of the tube in a like manner from H, leaving the part from 3 to 4 till last, this will give less straining to the flange and tend to keep the thickness of plate at the point 4 better than were the flanging commenced at any other part.

PROBLEM 46.

To develop a tube fitted centrically on a larger tube.

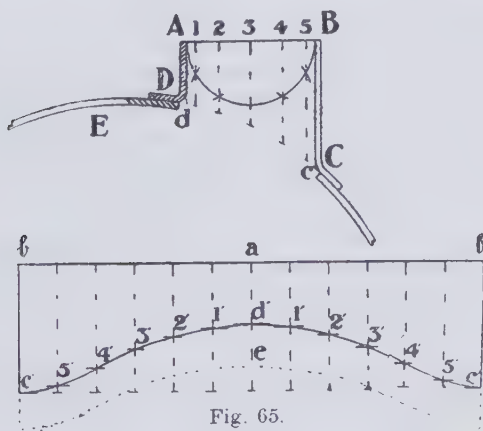
Let ABCD, fig. 63, represent a flanged tube fitted on the tube E. Divide the inside diameter of AB proportionally for projection in 1, 2, 3, 4, 5, and from these points draw lines parallel to AD till they meet the outside surface of E. Draw a line aa , fig. 64, and make it equal to the circumference of the tube at the centre of the iron; divide aa into 12 equal parts, and at each point and each end draw lines perpendicular to aa ; set off ad' equal to Ad , fig. 63, and taking the lines in succession from

AB, set them off from *aa* in 1', 2', 3', 4', 5', *c'*. Draw a fair curve through these points to complete the flange line, which will



be the line to $\frac{E}{C}$ be centre marked. Add on the required flange allowing a little extra at *ee*, and if *ad'* have to be butt edges extra should be allowed, at *f* to be jumped after flanging. If the tube has to have a lapped seam at *ad'*, that line will of course be the centre line for the holes, and the extra for flanging may be added as shown by dotted line at *g*.

In fig. 65 is shown a tube ABCD fitted to a larger tube



but not in central position. It may be developed by exactly the same process as is explained in the foregoing problem, though the shape of the lay-out is somewhat different, and in the figure the lines bb and $c'c'$ have been both divided into 12 equal parts and the points connected by lines and on these the lengths of lines from AB in $d, 1, 2, 3, 4, 5, c$, have been set out in $d', 1', 2'$, etc., through which the curve has been drawn giving the flanging line. The remarks as to flanging, butts, and lapped seams in reference to figs. 59 and 63 also apply to this figure.

PROBLEM 47.

To develop a tube fitted at an angle to a larger tube and out of centre.

AB , fig. 66, is an end view of the connection, ab being the side view, showing the angle of inclination in CD . Draw EF at right angles to CD , and from G , with radius equal to the inside radius of the tube a , draw the semi-circle ECF . With the same radius divide ECF into 6 equal parts, and from the points obtained draw lines parallel to CD , producing them well into the tube b . Project the line gg from G parallel to the tube b , and draw cd , the centre line of A , at right angles to gg . Project E and F to the line cd in e and f , and from cd set off gg equal to the inner radius of the tube A . gg and ef are the major and minor axes of an ellipse which represents the end view of EF . Draw the ellipse. Project all the points on EF by lines parallel to Gg till they cut the ellipse, as H to hh , and J to jj . Project all the points on the ellipse by lines parallel to cd till they meet the outside surface of the tube B , and again project these points on the surface of B by lines parallel to gG till they intersect their corresponding lines on b projected from EF , as in e'', f'', h'', j'' . A fair curve drawn through the intersections on b will be a side view of the flanging line of the smaller tube, and will be the line which will be centre marked for flanging.

The finding of the flanging line on b has been done by complete geometrical process, but an application of Problem 39, fig. 48,

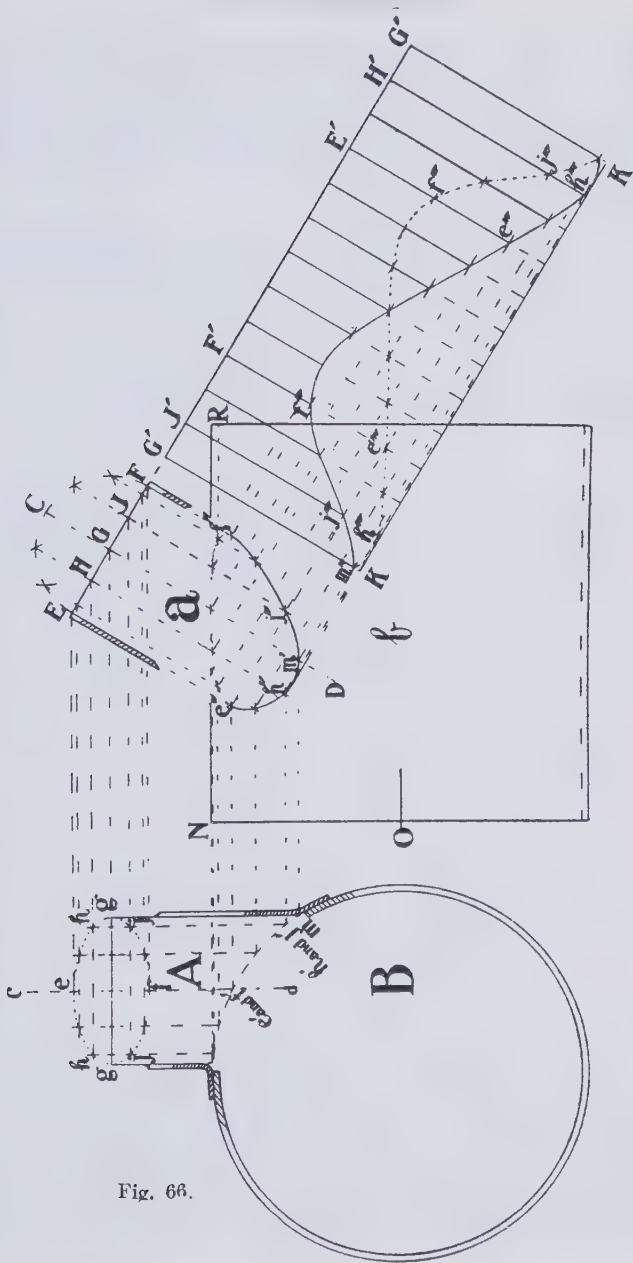


Fig. 66.

will save a certain amount of drawing, and will also tend to give greater accuracy, because EF may be divided proportionally for projection, rendering the semi-circle unnecessary, and the line *gg* may also be similarly divided, from which it will be seen the ellipse is not required.

In this problem the ellipse is shown as projected from EF to *gg*, *ef*, and is sometimes done in the following manner:— Find *gg*, *ef*, as before, then from all points on EF draw lines through *ef*, and on each side set off these lines equal to their corresponding lines in the semi-circle ECF; thus the points *h* and *j* are from *ef* equal to the lines H and J from EF to the semi-circle. Through the points obtained draw the ellipse.

To develop the tube *a*, draw G'G' equal to the circumference of *a* at the centre of thickness, and divide it into 12 equal parts. Draw G'K perpendicular to G'G', and of any convenient length. Draw KK parallel to G'G', and divide it into 12 equal parts; join the points on G'G' to those on KK. We will suppose the butt has to be on the line Gm'. Set off G'm" equal to Gm', J'j'" equal to Jj'', and so on in rotation for each line in the development; through these points draw a fair curve to complete the figure. By setting out the development in the reverse order, commencing at m' as before, but taking h" instead of j'', and following the rotation in that direction, the development will be as shown by the dotted line; this will be the correct one for the purpose, as it represents the inside of the tube, and this line must be centre marked for flanging. Add on the flange required, remembering to have extra where the stretching is severe, and complete the lay-out by marking the holes for the butt or seam as the case may be, and the necessary lap.

To avoid confusion of lines and lettering, fig. 67 has been traced from a portion of fig. 66, showing the line 1, 2, 3, 4, 5, corresponding to e'', h'', m', j'', f'', and having NO equal to NO in fig. 66. From this line it is now desired to lay out the shape of the hole in the tube *b*. By referring to B, fig. 66, it will be noticed the hole has to be larger than shown at *b*, in order to

allow for the turn of the flange of A so that there shall be no plate projecting beyond the surface of the flange.

From O as centre (fig. 67) describe arcs NP, representing the outside and inside surfaces of *b*, and also the centre of the thickness. Project the points 1 and 5 parallel to NR, meeting the *outside* surface in 1' and 5' (these will be represented by one point), and from this point draw a line to the centre O. Draw a line N'R', fig. 68, equal to NR, and draw another line N'P' at

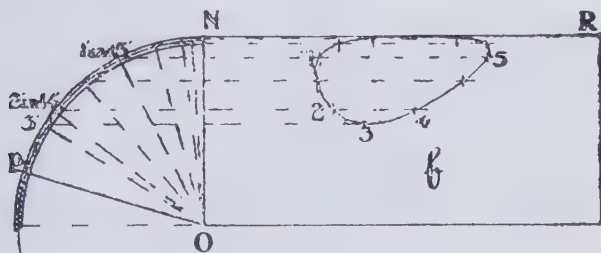


Fig. 67.

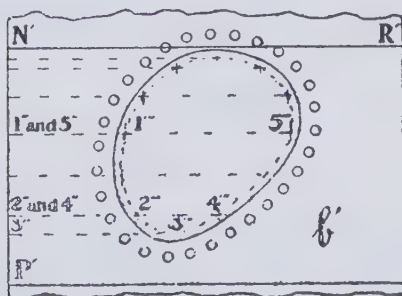


Fig. 68.

right angles to N'R'. From N' set off on N'P' a space N'1' equal to N1' *measured along the centre of the thickness*. From 1' draw a line parallel to N'R', and from the line N'P' make 1'1'', and 1'5'' equal to their corresponding distance from NO in fig. 67. Obtain all the other points in a like manner, and through them draw a fair curve as shown by dotted line in fig. 68. This line will be the position on the outside of the tube *b* where the inside of tube A would engage with it if produced, but as the hole has

to be larger, as shown in B, fig. 66, the heavy line has been drawn in a proper distance from the dotted line, and it is this heavy line which is to be the shape and size of the hole. The rivet holes may then be marked and will be on the proper side of the plate if they are to be punched, the drawing showing the outside of the tube.

CONSIDERATION OF THICKNESS OF PLATE WHEN DEVELOPING.

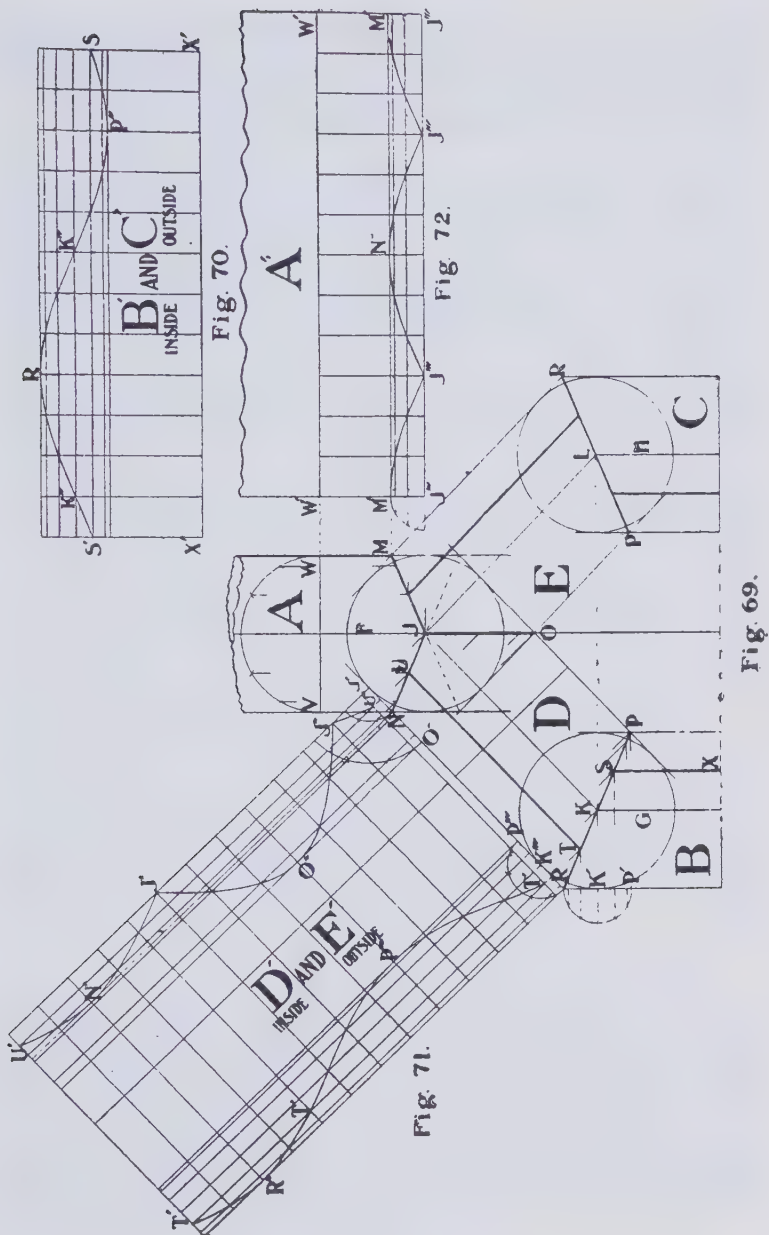
Though the principles of developments are not affected by thickness of plate, it is essential that thickness be considered when finding the line which has to be developed, and a reference to Problem 43 and sequence will make this clear to the reader. It is our desire to make the problems as free from complication as possible, and to avoid a confusion of lines. Having given what we believe to be a sufficient explanation of this matter, we will confine ourselves mainly to plain developments as we proceed, leaving it to the reader to make the differences which thickness may demand, always assuming he has realised and mastered the importance of the subject from the problems named.

PROBLEM 48.

To lay out a Y breeching, the tubes to be of equal diameter.

Let it be required to make a Y connection made up of tubes A, B, C, and their connecting tubes D and E, fig. 69, the bases of B and C to be in the same straight line, and the tube A to be in central position in relation to B and C.

Draw the centre line of A in F, and on each side draw the centre lines of B and C in G and H the proper distance from F. From a convenient point J on F draw the centre lines JK, and JL of equal length, these lines will be the centre lines of the connecting tubes D and E. About J, K, and L describe circles equal to the diameter of the tubes, and draw tangent lines to them parallel to all the centre lines; this will complete the outline of the connection. Where the tangent lines intersect at M, N. O.



draw lines to J, these lines will be the connecting lines as between the tubes A, D, and E. Where the tangent lines intersect about the circles described from K and L, join them by PR; these lines will be the connecting lines for the tubes BD, and CE.

To develop the tubes B and C, these being alike, project P to P' at right angles to G, and divide P'R proportionally for projection, then by Problem 39 set out the development as shown in fig. 70, where the seam is shown as on the line S'X' and the developed curve in S'S' passing through the points K''R'K''P''. The figure shows the inside of B and the outside of C.

For the development of the tube D, project P to P'' and divide P''R proportionally for projection, then by Problem 39 set out the development in T', P''', T', R'', T', fig. 71, the seam being on the line TU. Project J to J', and O to O', and divide J'O' proportionally for projection; J'O' being but half a rake height it will only be necessary to set off three divisions instead of six, as shown by the arc described from J' with radius J'O', then by Problem 39 set out that portion of the figure representing JO. OP being on the same line, O'' will be on the same line as P''', and from O'' trace in the curve through the intersections to J''J''. Divide J''N proportionally for projection as shown by the arc described from J' with radius J''N, and from these points draw lines through the development; NR being on the same line, N' will be on the same line as R'', then from N' trace the figure through the intersections to J'' and U', the small portion J''U' may then be traced to complete the development. The figure will show the inside of D and the outside of E, these tubes being alike.

To set out the development of the tube A in A', fig. 72, draw a line W'J'' parallel to WM, and to it project the points M and J at right angles to WM in M'J'', from J'' with radius J''M' describe the quadrant, and divide it into three equal parts as shown; project these points to M'J'', which will then be divided proportionally for projection, MJ, and NJ being half rakes. By again applying Problem 39 the development may be completed by the curves M', J'', N'', J'', M', and the figure will represent

either the inside or outside, the seam being on the line WM. All laps will require to be added.

By describing the circle from J, fig. 69, and drawing the tangent lines representing the outline of the figure, and then joining their intersections as at MJ, NJ, and OJ, a principle is introduced which will be found exceedingly useful in the laying out of branch connections. The principle is that of a globe around which the various tubes are made to engage, whether they be parallel or conical, and whether their angles to each other be symmetrical or not; and by enlarging on the principle, interpenetration may be determined from an elevation of cylinders and cones, when their centre lines meet, without the use of a plan or end view.

PROBLEM 49.

To set out the connection for three tubes of equal diameter not being in regular position, but in the same plane.

Let A, B, and C, fig. 73, represent the tubes which have to

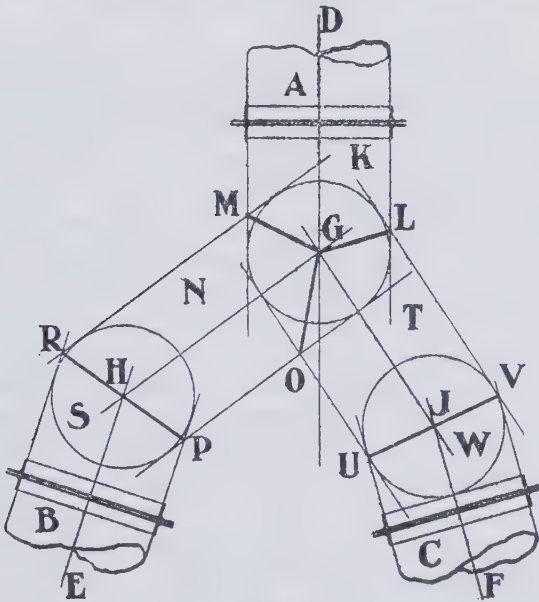


Fig. 73.

be connected, their endings at present being at the angle ring joints. Draw the centre lines, D E, and F, and at any convenient points G, H, and J, describe circles equal to the diameter of the tubes. Produce the outlines of the tubes by lines tangent to the circles, and draw the tangent lines from the circle G to circles H and J. Join the intersections about the circle G to the centre by lines LG, MG, OG; join the intersections about H by PR, and the intersections about J by UV. The development of K will be obtained from the angle ring joint as a base, and the connection lines LG, MG; N will be developed from R, M, G, O, P; S from the angle rings to P R; T from U, O, G, L, V; and W from the angle rings to UV. This will mean a connection made up of five tubes of equal diameter, and all may be laid out by an application of Problem 39.

Fig. 74 shows a connection made up of four tubes of equal

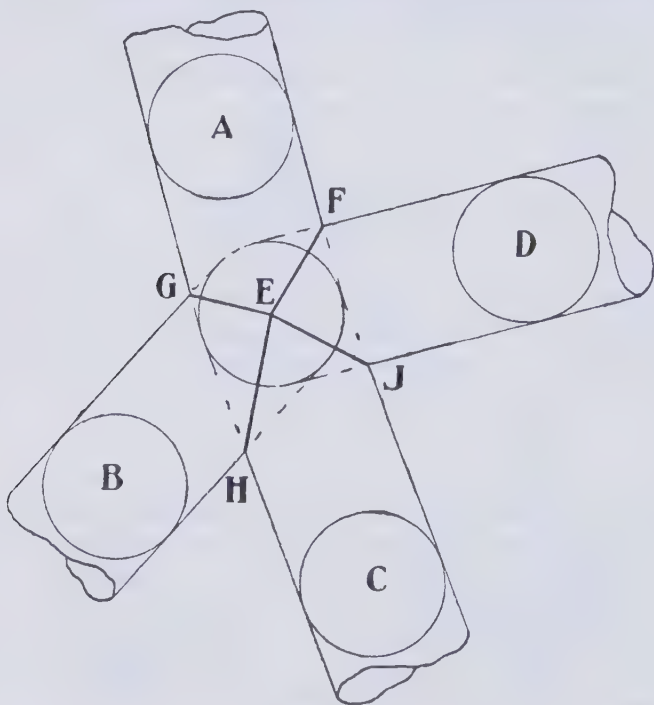


Fig. 74.

diameter, the connecting lines being FEG, GEH, HEJ, and JEF. Each of the tubes A, B, C, D, may be developed by Problem 39, and so may any number of tubes be connected by this method, the central circle around which they engage being the all-important factor in the problem, representing as it does, a sphere at whose centre the centre line of all the tubes meet. This principle may be enlarged upon for finding interpenetration lines by describing a number of circles to represent a number of spheres and where the circles intersect the outline of the tubes, cross lines may be drawn, and where they intersect will give a series of points through which the interpenetration line may be drawn. This is explained in the next problem.

PROBLEM 50.

To find the interpenetration between two tubes of equal diameter when their centre lines meet.

Draw the centre lines of the tubes A and B, fig. 75, at the required angle, meeting in C. From C with radius equal to half the diameter of the tubes, describe the circle D. Draw lines parallel to AC and BC, and tangent to D, intersecting at E and F. Join EC and FC; these lines will show the interpenetration. If it be assumed the circle D represents a sphere, and that it be cut by two intersecting planes GH, and JK, their intersection will be at C, and will be a straight line equal in length to the diameter of the tubes, because the planes make sections of the sphere through its full diameter passing through C, and the points G, H, J, K are where the tangents engage with D. If L be considered as a sphere, and the lines 1 2 and 3 4 are regarded as planes cutting it and intersecting each other at *a*, the straight line produced by the planes at that point will equal a straight line through the tubes at that point also, the planes being circles equal in diameter to the tubes; and similarly with M, if it be treated as a sphere cut by planes 5 6 and 7 8 they will intersect at *b*, which will be another point on the interpenetration line,

and so on for any number of points it may be desired to have, then a line drawn through these will be the interpenetration line required. The tubes in the figure being of equal diameter, the lines CE and CF are straight, forming a right angle at C, and for such a figure the principle of spherical treatment would of course

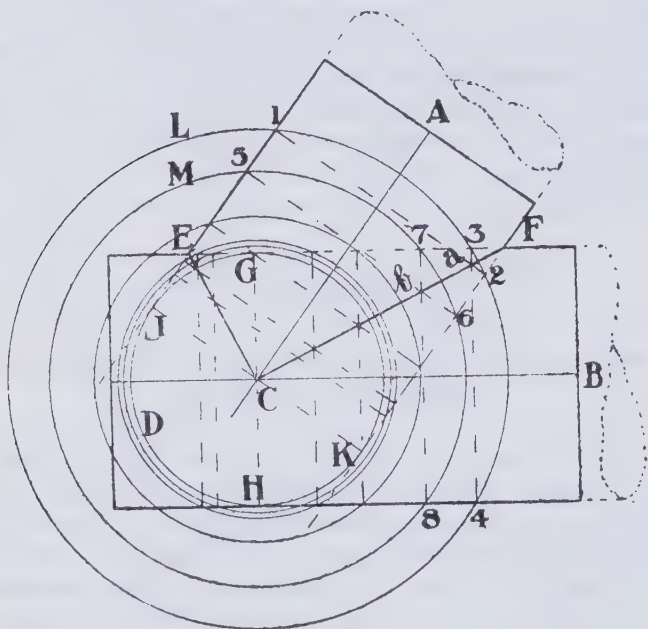


Fig. 75.

not be necessary, but it is here presented in order to illustrate the application of the method to a problem which will no doubt already be familiar, and therefore render the reader some assistance in grasping the method when applied to other problems. It must be remembered that it is only applied to cylinders and cones whose centre lines meet.

Another demonstration of the sphere principle.

Fig. 76 represents two tubes of unequal diameter, the curve DE being the line of interpenetration. The centre lines A and B

have been drawn meeting at C, and from C a number of arcs have been described intersecting both tubes. The points where the arc F intersects the tube A have been joined by the line 1 2, and where the same arc intersects the tube B, the points have been

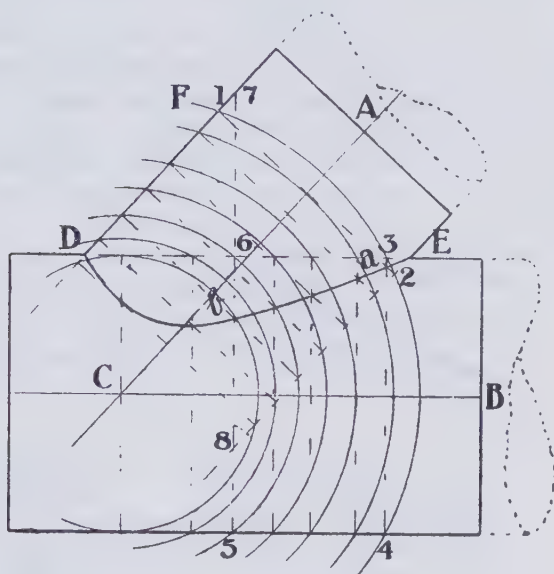


Fig. 76.

joined by the line 3 4; 1 2 and 3 4 intersect at *a*, giving one point on the interpenetration line. An indefinite number of points may be obtained in a similar manner through which the curve DE may be traced.

Another method of finding this curve without recourse to an end view is to take any number of parallel sections, and where the section of one tube engages with the section of the other tube produced by the same line, will be a point on the interpenetration—for instance, if the line 5 6 be produced to 7, it will cut the tube A in 8, then the section of A produced by the line 7 8 will be an ellipse, and the section of B produced by the line 5 6 will be a circle; where these sections cross will give a point *b* on the curve

DE. This method would of course be exceedingly tedious, and likely to be less accurately drawn than by spheres, or by side and end views, and it is therefore not to be recommended as a general method.

PROBLEM 5.

To find the connecting lines of three tubes of equal diameter, but whose centre lines do not meet in a common point.

Let A, B, and C, fig. 77, represent the three tubes which have

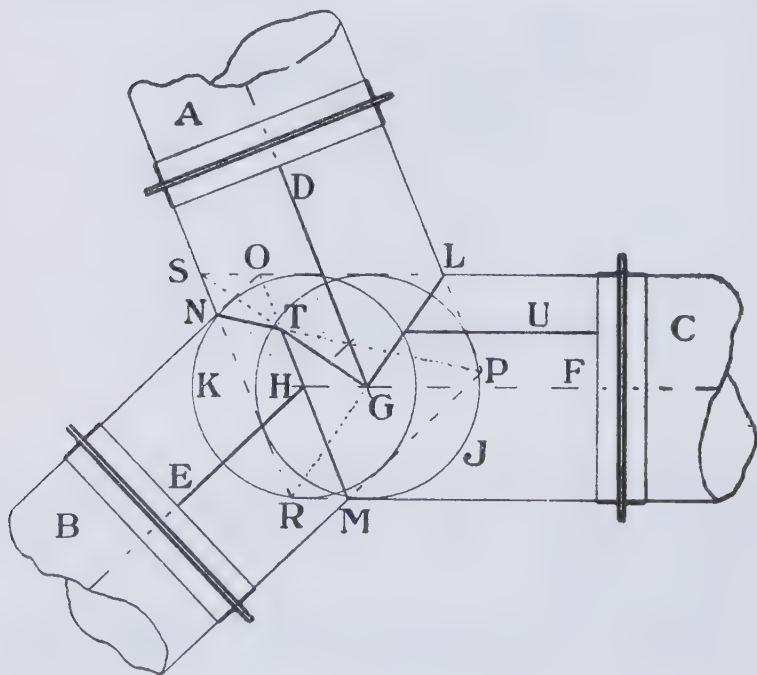


Fig. 77.

to be connected by means of extension tubes from the angle ring joints. Draw the centre lines D, E, and F; and where D and E meets F in G and H will be centres of circles J and K equal in diameter to the tubes; describe the circles. Produce the

sides of the tubes by lines drawn parallel to their centres and tangent to the circles J and K; these lines will intersect in points L, M, N, O, P, R, and S. If C be disregarded for the moment, the connection between A and B will be on the line NP, which must be drawn; if A be disregarded, the connection between B and C will be on the line MO, join MO intersecting NP in T; then, disregarding B, the connection between A and C will be on the line LR passing through G; this will leave a portion GT not yet set out. If the tube C be considered as continuous, the connection between it and A would be on the lines SG, GL, passing through T; join TG. The connection lines will then be for the tube A as follows, the angle ring joint as a base, and the lines NTGL, from which it should be developed. The tube from B will have for its connection the lines NTM; and the tube C will be connected at the lines LGTM.

The best lines for the seams will be on D, E, and U, and the three tubes may be developed by Problem 39.

PROBLEM 52.

Another method for the previous problem.

Where the tubes A, B, and C approach very near to a central position, a very good union may be made with two plates and three seams, and give a less obstructed flow to whatever has to pass through them. Draw the centre lines D, E, and F, and where these lines pass the edge of the angle rings as at G, H, and J, join them by lines forming the triangle GHJ. This triangle will be a flat surface. Join the edges of the angle rings by lines K, L, and M. Produce NO, and PR till they intersect at S, and draw ST at right angles to GJ. Divide GO and JR proportionally for projection, as shown by the semi-circles, and join the points obtained. Set off TU equal to the radius of the tubes, and with TU and T3' as half major and minor axes draw the quarter ellipse U3', passing through 1', 2'. From T set off on TS the points 1", 2", 3" equal to U 1', 2', 3', measured along the curve. From 1",

2", 3", describe the arcs 1"', 2"', and 3"' distant from ST equal to 1, 2, and 3 respectively, and from J with radius equal to one twelfth the circumference of the tube cut the arcs in 1"', 2"', 3"', and through these points draw a fair curve. Repeat the process from GO, and join 3"' 3"', which will be a seam line. Add the amount of flange required for the angle ring. Treat the other portions of the figure similarly from the lines L and M, and

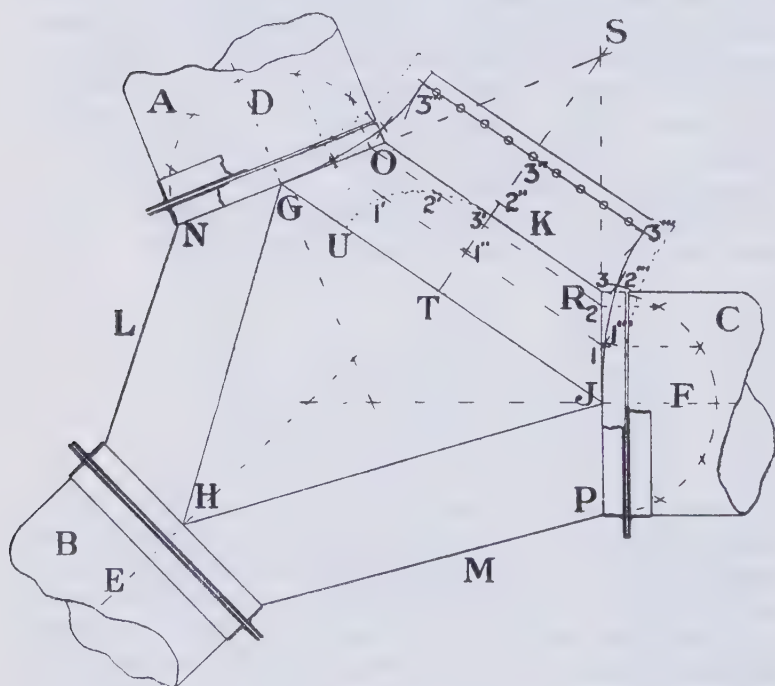


Fig. 78.

when the plate is cut out and punched, mark one off from it after turning the plate over. The portions outside the triangle may then be rolled to shape (which will be elliptical through the line ST) and bolted together at the seams, after which the flanging may be done to suit the angle rings.

Where the taper in the portion to be developed is considerable it is not always advisable to develop from the line TS as a basis, but rather to set out the plate in the manner shown in the next figure where the points 1, 2, and 3 projected from the semi-circles have been joined showing the gradual taper in the direction from F to E. Through the points 1 draw lines 1' at right angles to EF; through the points 2 draw lines 2' at right angles to 1 1,

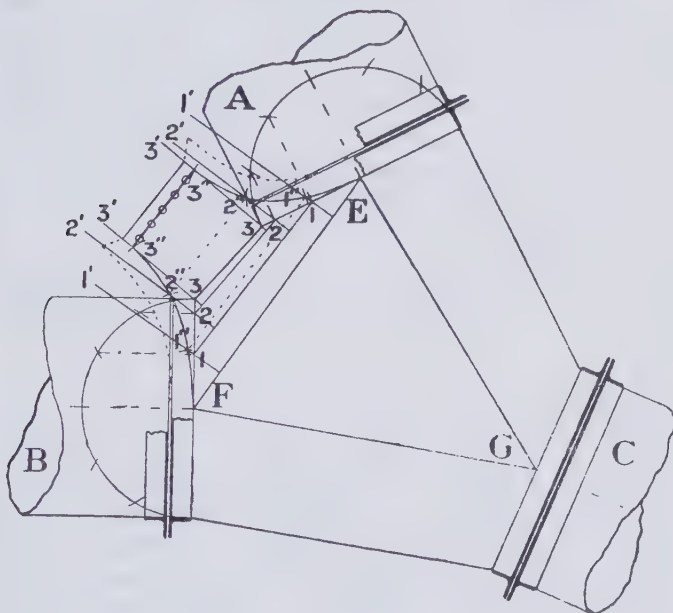


Fig. 79.

and through the points 3 draw lines 3' at right angles to 2 2; then from E. and F with radius equal to one twelfth the circumference of the tubes cut lines 1' in 1", and from 1" cut lines 2' in 2", and again from 2" cut lines 3' in 3", and through these points draw fair curves. Join 3" 3", which will be the seam line; add on the required flange, and develop from EG, and FG in a similar manner to complete the figure.

In this development the more divisions on the semi-circle the better, as it is assumed the portion from EF to 1 1 is rolled

square to EF at all times, whereas it is not so, strictly speaking, and by taking a greater number of divisions from E to 3 and F to 3 proportionately greater accuracy will be obtained.

PLANS AND ELEVATIONS, AND TRUE LENGTH OF LINES.

Though there are almost innumerable figures which show their true length of lines in either the plan or elevation so far as the requirements of their development are concerned, there are equally innumerable figures which do not possess this advantage, and while the problems given in the preceding pages have in no case involved the finding of true lengths, but have been of that character which permits of treatment from the lines on one view only, we think it necessary to make a brief reference to the subject of true lengths by way of illustrating its importance in the development of those figures which are of a more complicated nature, and which have to be set out from plan and elevation.

A plan is that view of a figure which would be shown on a horizontal surface or plane if all points of the figure were projected to it by lines at right angles to the plane; this plane is referred to as the H.P. An elevation is that view of a figure which would be shown on a vertical surface or plane if all points of the figure were projected to it by lines at right angles to the plane; this plane is called the V.P., and these planes are at right angles to each other and their line of contact is known as XY.

In fig. 80 is shown six illustrations of plans and elevations, the first being that of a point in space, A representing the elevation and *a* the plan. The distance of A from XY will be the height of the point from the H.P., and the distance of *a* from XY will be its distance from the V.P. The second represents the elevation and plan of a line in space, AB being the elevation and *a* the plan; as the plan is a point it shows that the line is at right angles to the H.P. and parallel to the V.P., and its distance from the V.P. is *a* from XY, whilst B shows its nearest point or end

as its height from the H.P. The third shows a line in space parallel to the H.P. and at right angles to the V.P., the conditions being exactly reverse to the previous illustration. The fourth is that of a line in space parallel to both planes, its height above the H.P. being $A.B.$, and its distance from the V.P. ab from

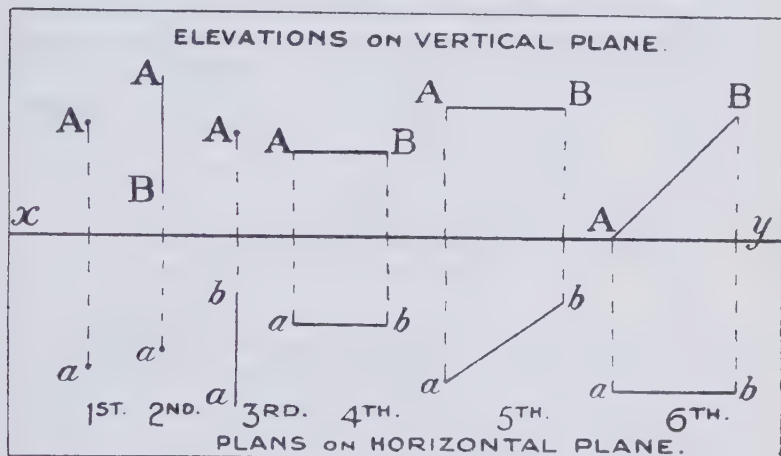


Fig. 80.

XY. The fifth shows a line in space parallel to the H.P., and at an angle to the V.P., AB being parallel to XY , the plan ab will show the true length of the line. The sixth shows a line parallel to the V.P., with one end touching the H.P. and at an angle to it; ab being parallel to XY , AB will be the true length of the line.

From the fifth and sixth illustrations it will be seen that a line which is parallel to a plane will show its true length on that plane, but if the conditions are such that neither the plan nor the elevation of the line is parallel to XY , then neither view will show the true length; in such a case it will be necessary to bring one view parallel to XY , keeping one end stationary, and project the other end to a line on the other view drawn parallel to XY from that view of the point projected, this will give a new point which must be connected to the stationary point, and will be the true length of the line. This is explained in

fig 81, where in the first instance is shown a line AB with the end A at the line of contact between the H.P. and V.P., the plan being Ab. To find the true length; from A with radius A.B. describe

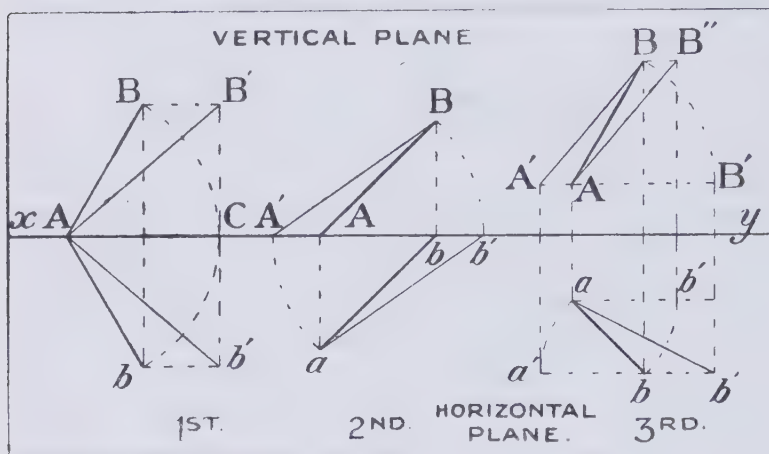


Fig. 81.

an arc BC, this will be bringing AB parallel to XY; project C to b' on the line bb' drawn parallel to XY; join $b'A$, which will be the true length of AB. Exactly the reverse has been done to show the true length in the elevation in $B'A$.

The second is that of a line AB resting on the H.P. and touching the V.P. but at an angle to both. To find the true length: from A with radius AB cut XY in b' , join $b'a$, which will be the true length of A.B. A and b being already on XY, there will be no projecting to do beyond that of the arc. The reverse has been done from b to find the true length $A'B$ in the elevation.

The third shows a line in space at an angle to both planes AB, being the elevation, and ab the plan. To show the true length in the plan, from A draw a line parallel to XY, and with radius A B cut it in B' , from b draw a line parallel to XY, and to it project the point B' in b' , join $b'a$, which will be the true length of AB. The reverse has been done from ab to show the true length in the

elevation in AB'' . If it be desired to show a view of this length with the end B stationary, draw a line from b parallel to XY and equal to ba ; draw a line AA' parallel to XY , and to it project the point a' , join $A'B$, which will be the true length of AB . From this illustration it will be noticed the stationary point or end of a line in one view is the stationary point in the other view. While these illustrations may be sufficient for our purpose, there are many ways that may be adopted to explain the subject, but for a complete study of solid geometry recourse may be had to one of the many excellent works already published.

DEVELOPMENT OF CONICAL AND OTHER INTERPENETRATING FIGURES.

With interpenetrating figures it frequently happens that there is considerably more work involved in finding the line of interpenetration, or connecting line, than in developing the various parts after this line has been found, but there is one class of inter-

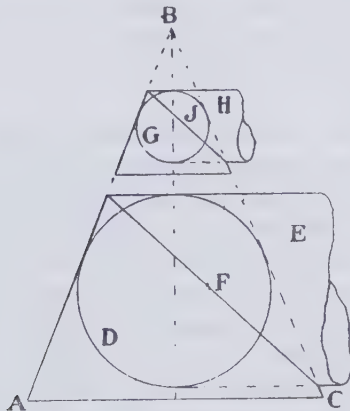


Fig. 82.

penetration which is an exception, and it is where the parts to be connected are either cylinders and cylinders, cones and cones,

or a combination of both cylinders and cones, whose centre lines intersect at the centre of a circle which touches the outline of the parts to be connected. This has been dealt with in regard to cylinders and cylinders in Problem 49, and it will be observed the centre of the circle is the meeting point for the lines of connection, but where the parts are composed of cones, or cone and cylinder, the central point of the connection will not necessarily be at the centre of the circle. In fig. 82 a circle D has been described just touching the cone ABC; now if D be taken as the size of a cylinder which has to be connected to a part of the cone it will



Fig. 83. only be necessary to draw parallel lines tangent to the circle and at the required angle, and where the tangent lines meet the sides of the cone will be the points to be joined to give the line of section common to both. In the figure the cylinder E has been drawn at right angles to the centre line of the cone, and the points joined by the line F; this line will not pass through the centre of the circle. In a similar manner the circle G has been described and the tube H drawn tangent to it, giving the line J as the section common to both cone and cylinder. It will be noticed that H being parallel to E, J is parallel to F when the angle ABC is constant. This is the method used by sheet-iron workers when making ventilator cowls of the pattern shown in fig. 83.

Fig. 84 shows an application of this principle to two cones and a cylinder whose centre lines meet at a common point O, and whose outlines are tangent to the same circle described from that point. Where the outlines intersect in what might be termed internally, join them by lines DE, FG, and HJ intersecting at the point K. The lines of common section of the tube and cones will now be DKF for A, DKJ for B, and FKJ for C; the point K will not be at the centre of the circle. If the external intersections be joined, as LM, NP, and RS, it will be found they cut each other on the lines drawn from the internal intersections, and they will also be lines of common section between AB, BC, and CA respectively.

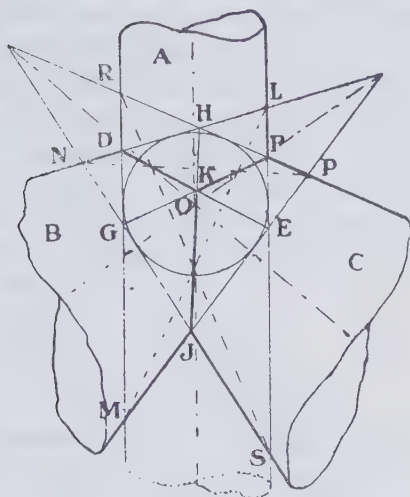


Fig. 84.

PROBLEM 53.

To develop the frustum of a cone, ABCD, fig. 85.

Produce the sides of the frustum till they meet at E; bisect AD in F, and join EF, producing the line well below XY. From F with radius FA or FD describe the semi-circle, and with the same radius divide it into six equal parts; project the points on the semi-circle to AD in 1, 2, 3 and 4. Draw lines from 1, 2, 3, and 4 to E cutting BC in 1', 2', 3', 4', the point G will be on the line EF. Project all the points on BC to the side of the cone ED by lines drawn parallel to AD. From E with radius ED describe the arc DD and make it equal to the circumference of AD; divide DD into twelve equal parts and from each point draw a line to E. From E as centre describe a series of arcs from the points on ED cutting the lines drawn from DD to E in 4", 3", 2", 1", b, through which draw a fair curve to complete the development

Instead of describing the semi-circle from F, the base of the frustum AD may be divided proportionally for projection by Problem 39, but the divisions on BC will require to be found by lines drawn to E, as these are not in the same proportion as those

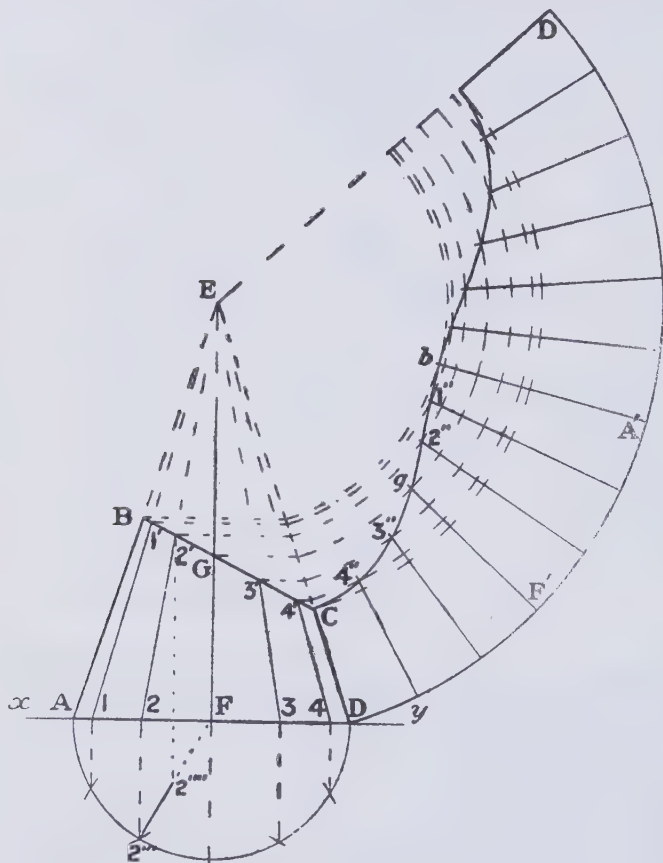


Fig. 85.

on AD. The reason the points on BC are projected to ED is because the lines 1 1', 2 2', etc., do not show their true lengths until so projected, which is equal to revolving the cone until each line in succession is shown at the side. The plan of 2 2', is 2'' 2'''

on the line 2''F, and if it is regarded as a part of E2 in the elevation and F2'' in the plan, it will be seen by fig. 81, second illustration, how the true length is found.

It is always best to make calculations for cones from the base for setting out the development because any inaccuracy will become less as the apex is approached, whereas if the calculation be made from a diameter nearer the apex and then set out, any inaccuracy would increase as the distance from the apex became greater—not that such is at all likely to be made, but this advice is as a precautionary measure.

PROBLEM 54.

To develop the frustrum of a cone when the apex is inaccessible.

Let ABCD, fig. 86, represent the frustrum standing on the ground line XY. Produce DC, and make DE equal to AB. Join BE, which should then be parallel to AD. Divide AD, and BE proportionally for projection, and join the points obtained by lines cutting BC in 1, 2, 3, 4, 5. Project these points to DE by lines drawn parallel to AD. From D with radius DB describe an arc at B', and with the same radius from E describe an arc at A', then from D with radius DA cut the arc at A', and from E with radius EB cut the arc at B'; join EB', B'A', and A'D. In the same manner set out from B'A' the portion E'D', and again from E'D' set out B''A''. Now by means of a triangular template applied to the points D' A' D, draw the curve from D to D', then remove the pin to H A', and the pin J to A'', and apply the template to the points A''D'A', as shown by broken lines, when the curve may be continued to A''.

As we purpose setting out only half the development, the curve traced from D to D' will be sufficient, and the inner curve from E to E' must be drawn by means of the same mould. Calculate the circumference of AD, and divide it into twelve equal parts; set off along the curve on each side of A' three divisions; calculate again from BE and set off along the curve on each side of B' three

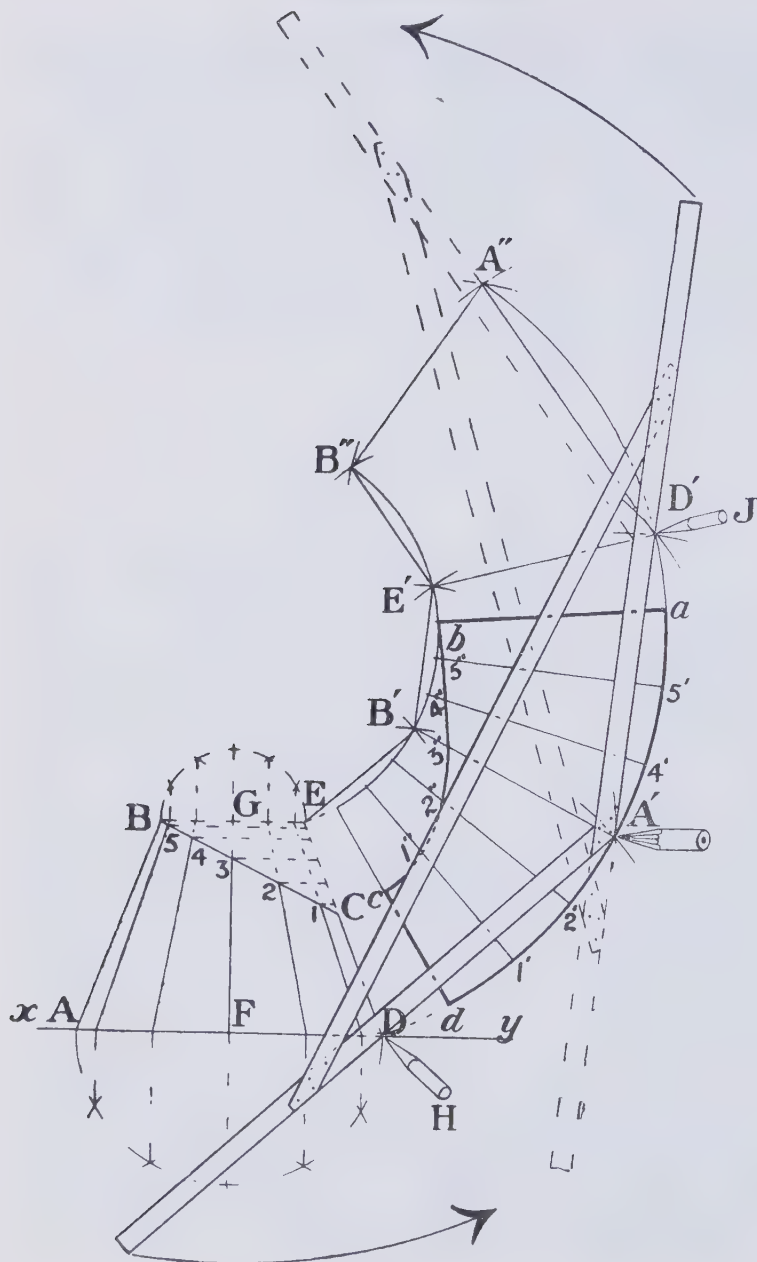


Fig. 86.

divisions, join those on the outer curve to those on the inner curve, and taking the divisions on DE, set them off from the outer curve of the development in rotation as dc equal to DC, etc., producing the points c , $1''$, $2''$, $3''$, $4''$, $5''$, b , then the development will be complete in $abcd$.

The principle and use of the triangular mould is explained in Problem 30, page 18.

PROBLEM 55.

To set out the connections for two tubes of equal diameter, and a third equal in area to the two combined.

Let A, fig. 87, be the tube which is equal to B and C combined, B and C being parallel to A and evenly disposed on either side of its centre line produced, the present terminations of all three tubes being at the angle ring joints as shown.

By an application of the principle explained on page 74, fig. 84, the whole of the connection may be determined. Produce the centre lines of A, B, and C, and at any convenient points D, E, and F, describe circles equal to the diameter of B and C. The reason the circles are to be equal to B and C is because it is desired to have the continuation of these tubes the same diameter as B and C, and also the two connecting tubes UV leading off from the elbows. From the angle rings draw tangent lines to the circles, and also tangent lines from the circle D to the circles E and F, and where they intersect join the points as GH, JK, LM, NO, and PR; it will be noticed the lines LM, NO, and PR all intersect at S, which is *not* the centre of the circle D. The tube from A will be conical, with its apex at T, and its connecting lines will be at LSN. The tubes from B and C will be parallel and alike, with their connecting lines at GH and JK. The intermediate tubes U and V will be parallel and alike with their connecting lines at GH, and LSR for U; and JK, and NSR for V. The development of the cone piece has been set out by Problem 53, the seam

being at N.W. The tubes U, V, and those from B and C may be developed by Problems 42 and 43.

When setting out the developments for U V and the tubes from B and C the seams may be placed at any position, but should be disposed so as to avoid "splaying" when flanging, and still

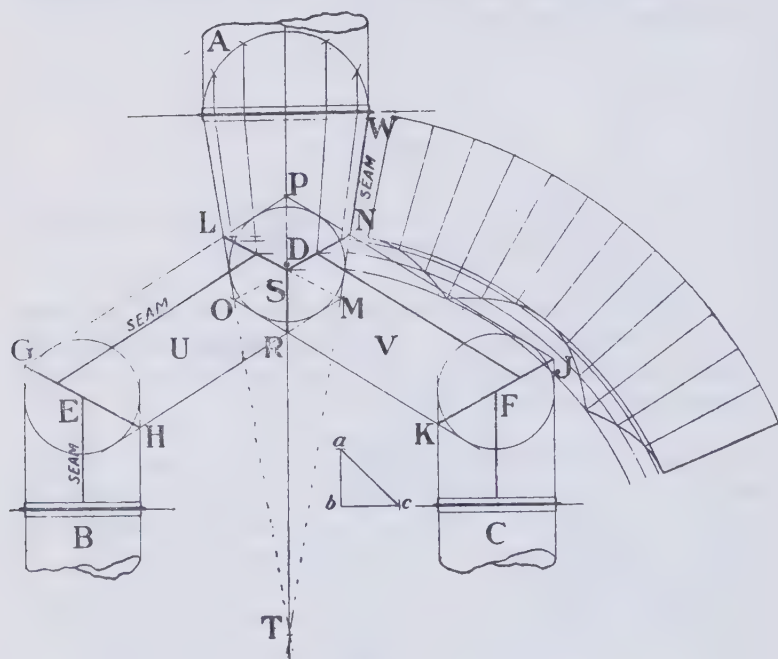


Fig. 87.

not have too many thicknesses at the joint holes. The outlines of the figure should be noted when developing, as they will be the best guide when connecting up.

If the tubes B and C had been given, and the size of A had to be found to equal the combined areas of B and C, it would be necessary to set out a right angled triangle abc , having ab equal to the radius of B, bc equal to the radius of C, then the hypotenuse ac would be the radius required for A. This is shown in the small diagram in the figure.

PROBLEM 56.

To find the interpenetration of a cylinder and cone when their centre lines meet, and to develop a portion of the cone showing the hole.

Let ABC, fig. 88. represent the cone on the line XY, and D

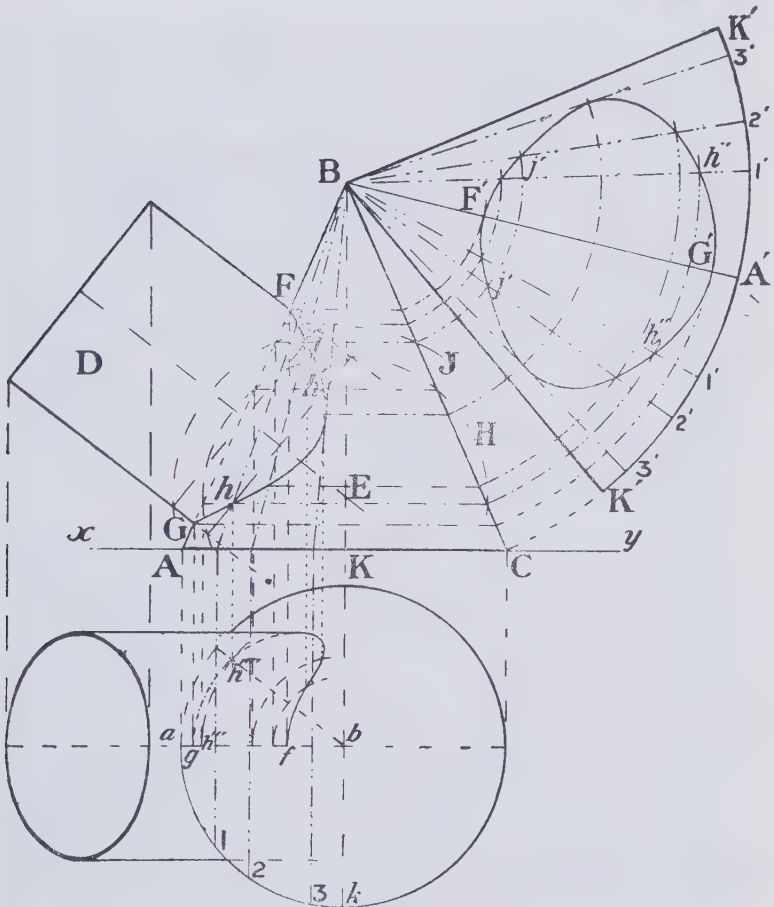


Fig. 88.

the cylinder; the centre lines will meet at E, and the sides of the cylinder will meet the cone at F and G. From E describe a series

of arcs as H and J intersecting the cone and cylinder ; join the intersections on the cone by lines parallel to its base, and those on the cylinder by lines at right angles to its centre line, these lines will cut each other at h , h' , and j . From F draw a fair curve to G passing through the points h , h' , j , which will be the interpenetration line.

To set out the development, produce BK below XY and from any convenient point b as centre with radius KA describe the quadrant bak , having ba parallel to XY. From B draw any number of lines to AK passing through the interpenetration line, and from their points on AK project them at right angles to XY till they meet the quadrant as at 1, 2, and 3. Project F and G to B.C., and also all the points on the interpenetration line produced by the lines drawn from B to AK. From B with radius BC describe the arc $K'K'$, and from a point A' set off $1'$, $2'$, $3'$, K' equal to 1, 2, 3, and k from a on the quadrant, and from these points draw lines to B. From B as centre describe arcs from the points on BC till they intersect the straight lines in the development as at G' , h'' , j' , F' , and through these points draw a fair curve which will be the shape of the hole in the cone.

Though a plan of the interpenetration line is not required for the purpose of the development of either the cone or the cylinder, it may be obtained in the following manner :—Project F and G to ab in f and g ; these will be points in the plan because they are on ab corresponding to AB. Project h to AB parallel to AC and from its point on AB project again to ab in h'' , from b with radius bh'' describe an arc, and to this arc project the point h in h''' . Find any number of points in a similar manner and through them draw a fair curve to complete the plan of the interpenetration line. Another way to find the plan is to draw any number of lines from B through the interpenetration line to the base AC, and from the base project the points again to the circle in the plan, and from the points on the circle draw lines to the centre b , and to these lines in the plan project the points in the elevation as with h to h''' ; this will give a series of points through which draw the required curve.

The cylinder D may be developed by Problem 45, using only the elevation shown in this figure.

PROBLEM 57.

To find the interpenetration of a cylinder and cone when the centre of the cylinder does not meet the centre of the cone.

Let A, fig. 89, represent the cylinder, and BCD the cone shown in the elevation on the line XY, the plan is of half the cone represented by the semi-circle BD described from *c*, and the cylinder at *a*. Draw the centre line of the cylinder EF and the sides intersecting the cone at G and H producing them well into the cone. From H draw a line parallel to BD cutting the centre line of the cylinder in J, the centre line of the cone in K, the side of the cylinder produced in L, and the opposite side of the cone in M. The line HM will then have cut the cylinder and cone in such a manner that the section of the cylinder will be an ellipse and the section of the cone will be a circle, and where these sections intersect each other will be two points common to both, and will be two points on the interpenetration line. Draw *ef* the centre line of the cylinder in the plan, and to it project the points H, J and L in *h*, *j*, and *l*; then about *j* draw an ellipse with *hl* as major axis, and the diameter of the cylinder *a* as minor axis, this ellipse will be the plan of HL. Project M to *m* on BD and from *c* with radius *cm* describe a semi-circle *mkh'* cutting the ellipse in points 1 and 2, these points will be on the line of interpenetration. Project the points 1 and 2 to the line HL in J and 2' which will give the positions of these points on the interpenetration line in the elevation. In this way any number of sections may be used to obtain points through which to draw the interpenetration line, the ellipses will be all the same size, but the semi-circles will be of different radii according to the position of the sections in the elevation, and when finding the points in the plan it is best to describe the semi-circles first, then project the centres of the ellipses to the line

circle mkh' without drawing in the complete ellipse. The fact that point J is on the centre line EF, and also on the interpenetration line is but a coincidence, due to the angle of the cylinder to the cone.

To set out the development of that portion of the cone through which the hole is traced, draw lines from c through all the points on the interpenetration line in the plan meeting the arc BO; the reason the lines should be drawn through these points is that they are on the lines of common section in the elevation, and where these lines on the elevation cut the side of the cone BC will be the points from which to describe the arcs in the development. From C describe the arc $B' O'$, and make it equal to BO measured along the curve, join $B'C$, and $O'C$, and from B' set off along the arc the same divisions as are on the arc BO, and from these points draw lines to C. From C, as centre, describe arcs from the points on CB cutting their corresponding lines in the development as at $1' 2''$, and through the intersections draw a fair curve to complete the figure.

To develop the cylinder, set off $E'E'$ equal to the circumference and divide it into twelve equal parts. From each point draw a line perpendicular to $E'E'$. Divide the diameter of the tube proportionally for projection, and from the points obtained draw lines to the interpenetration line, then with the lengths of these lines taken in rotation set them off from $E'E'$ as $E'J'$, and through the points draw a fair curve to complete the development. It will be noticed all the lines on A except the side lines will give two points each for the development as $2' 3$ which when set out gives $2'' 3'$.

The figure in miniature is the elevation of the whole when complete.

ALTERATION OF THE GROUND LINE X Y.

There may be occasions when a workman has to set out figures from a drawing which does not show the true lengths of the parts

to be made up, the various figures forming the whole being at an angle to both planes, and where this is met with it will be necessary for the correct setting out that the proper lengths and positions be found. This may be explained by referring to fig. 81, page 72, and taking the first illustration in the fig. let AB represent the elevation of the *centre* line of a cylinder, and $A\hat{b}$ the plan of the same line; the cylinder cannot be developed from these lines direct, but will require to be revolved until one view (generally the plan) is parallel to the line XY , and the other view so altered by reason of this revolving that it shows the true position and length; thus in the figure the point b has been revolved to C and then projected to B' a distance from XY equal to B , then BA is the true length of the tube, and if it were supposed the end A is cut to a bevel to lie evenly on the horizontal plane, the bev'el formed by $B'A$ and the line XY will be the correct bevel required.

This revolving of a figure is equivalent to changing the ground line as will be seen in fig. 90, where VR is the elevation of a line

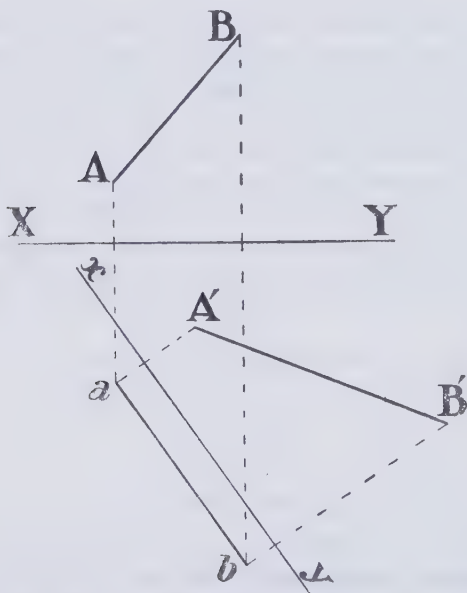


Fig. 90.

and $a b$ is the plan, and it is required to show its true length when the ground line is parallel to $a b$. Draw the new ground line $x y$ parallel to $a b$, and from a and b draw projectors to the elevation in $A'B'$, making them equal in length above the line $x y$ to their corresponding lines above XY ; join the points $A'B'$, which will be the true length of the line in the new position.

As a further illustration of the changing of the ground line, let it be required to show the elevation of a pyramid when the new ground line is at an angle of 60 degrees to the first ground line, in other words, when the new vertical plane is at an angle of 60 degrees to the original vertical plane.

Let ABC , fig. 91, represent the elevation of the pyramid on the line XY , and $a b c d e$ the plan below XY . Draw the new

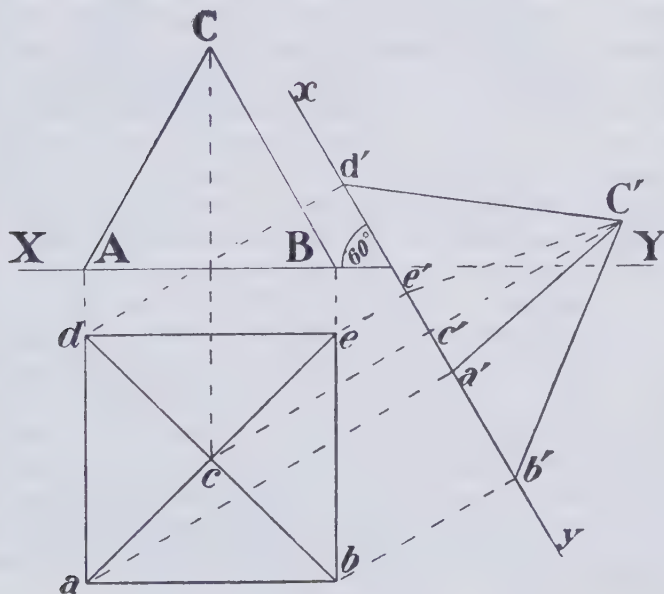


Fig. 91.

ground line $x y$ at the required angle to XY , and to it project the points $a b c d e$ at right angles to $x y$, the point c being the plan of the apex, produce the new line above $x y$ in C' equal to

C above XY; draw lines from the points on xy to C' to complete the new elevation.

In fig. 89, the cylinder is shown in the plan as being parallel to XY, and therefore the finding of the interpenetration line is proceeded with directly from the plan and elevation, but were the view of the cylinder given as at an angle to both planes, it would be necessary to revolve the figure till the plan became parallel to XY, and the true view of the elevation shown in accordance with this new position. Fig. 92 shows a cone ABC on the line XY, the plan being the circle described from b as centre. The elevation and plan of the centre line of a cylinder is given in ED and ed , the line terminating on the base of the cone. As neither view is parallel to XY, the figure must be either revolved or a new ground line drawn parallel to the plan of the cylinder, and a new elevation projected, but it is usually more convenient to revolve the figure. From b as centre and radius just touching the line ed at f describe an arc g , draw a line F tangent to the arc and parallel to XY. From b with radius be cut the line F in e' and again with radius bd cut the line F in d' then $e'd'$ will be the plan of the line revolved parallel to XY. Project e' to XY in E' , and d' to D' equal to D in height above XY; join $D'E'$ which will be the new elevation of the centre line DE. Set out the cylinder having the end at D' square with $D'E'$, and produce the sides till they meet the base of the cone in H and J, then HJ will be the major axis of the ellipse at that end of the cylinder; project H and J to the line F in h and j . Draw the outside lines of the cylinder in the plan on each side of the line F, and about e' draw the ellipse $h j$. The interpenetration line at K and k may now be found by the method explained in Prob. 57, fig. 89, and if it is desired to develop the cylinder it may be done from the new elevation both as regards the bevel at the base of the cone and also the interpenetration, the development of the hole in the cone being done by the method explained in the same problem.

Should it be required to revolve the figure back to its original position and show the full view, draw in the plan about the line de exactly the same as that about the line $d'e'$. Divide the end

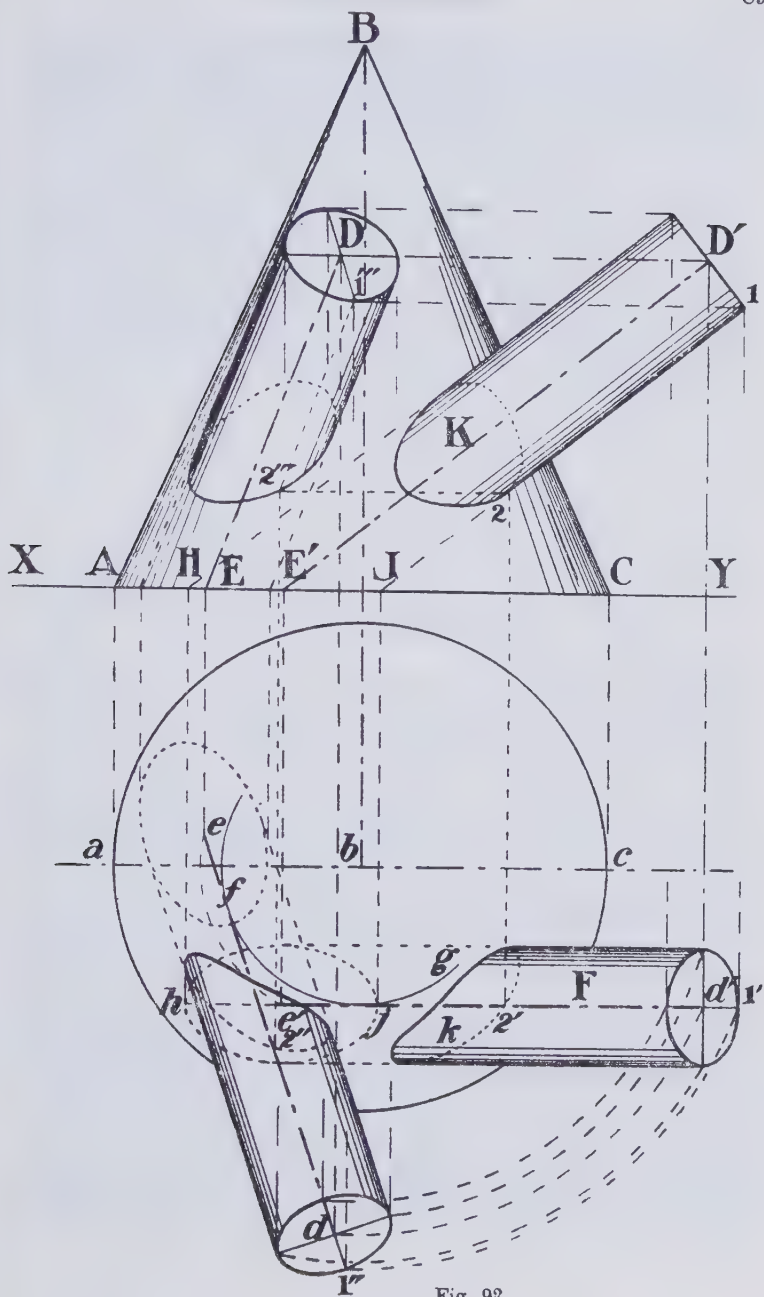


Fig. 92.

of the cylinder at D' proportionally for projection (Prob. 39, fig. 48), and project the points obtained to the ellipse at d' , and again to the ellipse at d by arcs described from b as centre. Draw lines from the points on the diameter at D' towards D , and lines from the points on the ellipse at d till they cut those drawn from D' in a series of intersections through which an ellipse may be drawn. This may be followed better if the point 1 be traced through its projections; and similarly the point 2 has been revolved to its position in $2''$, in this manner any number of points may be projected giving intersecting lines through which the revolved view of the interpenetration line may be drawn.

PROBLEM 58.

To develop a union of three tubes of equal diameter and length, each to be at right angles to the others.

Draw the line XY , fig. 93, and above it set out the elevation of the union in A , B , and C , having a common centre at D ; the tube C is represented by a circle. Draw the plan in a, b , and c , having a common centre at d , the tube A is now shown in the plan as a circle. If any tube be neglected the remaining two may be considered as being connected by an ordinary elbow, but as the third tube has to engage upon the elbow, the two tubes will have a portion cut away to suit this, and if it were of no consequence where the seams had to be the three tubes may be made alike, and the development of one would be sufficient for the lay-out of all, the only thing to be careful about being to have the proper sides of the plate up when rolling. Having set out the plan and elevation, join the tubes b and c by the line $e5$, and the tubes A and B by the line $f8$, these lines will pass through the centre of each circle. On the end of the tube c describe a semi-circle $g h$ and divide it into six equal parts, through each point on the semi-circle draw a line to the elevation and parallel to the centre line of the tube c , these lines will cut the circle at a and the line $e5$ in

the points 1, 2 & 8, 4 & 6, 15 & 9, 13 & 11, the point 12 will be opposite *d* parallel to XY. Where the line *e5* cuts the circle will be extra points which indicate the place where the connection as between *a* and *b* changes to that between *a* and *c*, these points

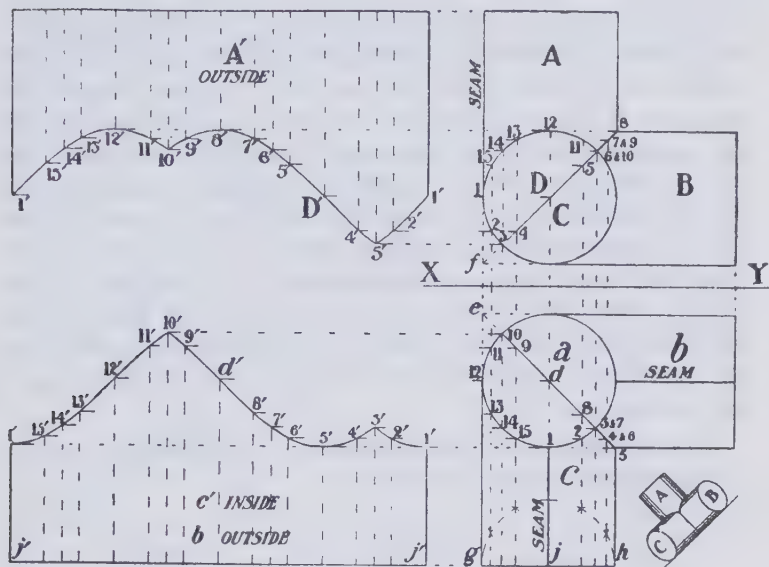


Fig. 93.

are to be projected to the semi-circle in order that their positions in the development may be determined; as the point 3 also represents the point 7 it is numbered accordingly, the other being 10, and the line drawn from 10 to the semi-circle will give the point 14 on the circle.

We will assume the seams are to be on the lines marked "seam," that for *c* being *j1*. Strike the line *j'j'*, and make it equal to the circumference of *c*, divide the line into twelve equal parts, and at each point draw a line perpendicular to *j'j'*. Make *j'1'* equal to *j1*, and taking the lengths from *g h* in rotation, set them off from *j'j'* in 2', 4', 5', 6', 8', *d'*, 9', 11', 12', 13', 15'; this will leave the points 3', 7', 10', and 14' still to be set out. Draw lines per-

pendicular to $j'j'$ evenly between $2'4'$, $6'8'$, $9'11'$, and $13'15'$, and set off their lengths from $j'j'$ equal to their corresponding lengths from $g h$. Draw fair curves from $1'$ to $3'$, $3'$ to $10'$, and $10'$ to $1'$ to complete the development which will represent the inside of c and the outside of b .

As the figure is numbered in the plan and development, it will probably be easier to understand than were the more direct process used, for as presented, the line of contact between the tubes may be followed from point to point, but it should be noticed the points obtained from the straight line $5,d,10$ are exactly the same as are found on the semi-circle described from d , and in setting out the development the points could be taken in rotation from 1 to 2, 3, then returning along the circle in 2, 1, 15, &c., to 10, from which point return again through 11, 12, &c., to 1. The tube A may be set out in the same manner from the points on the semi-circle described from D, as 1, 2, 3, returning through 2, &c., to 6, from which point return again through 11, &c., to 1 to complete the development.

The miniature shows the elevation of the tubes when viewed from its position in relation to $a b c$.

PROBLEM 59.

To develop a union of three tubes A, B, C ; A to be at right angles to B and C, but B and C not to form a right angle.

Draw the line XY, fig. 94, and set out the plan of the tubes in a, b, c , having the point d as a common centre and the tube c at right angles to XY ; the circle described from d as centre will be the plan of the tube A. Produce the sides of b and c till they meet at e , join $e f$. Draw the elevation A,B,C, the ellipse at the end of B being projected from the plan by the method explained in Problem 47.

The development of b and c will be alike, and will take the form of two rake lines crossing each other, one height of rake being $f' e$, and the other equal to the diameter of the tube a , their

points of crossing being at 3 and 8 where the line ef crosses the circle. From g describe a semi-circle, and divide it into six equal parts; then from each point draw a line to the elevation, cutting the circle about d in the points 9, 11, 12, 1, 2, and the line ef in 7, d , 6, 4. The point 10 will be opposite d parallel to XY . Set off $g'g'$ equal to the circumference of c , and divide it into twelve equal parts, and at each point draw a line at right angles to $g'g'$.

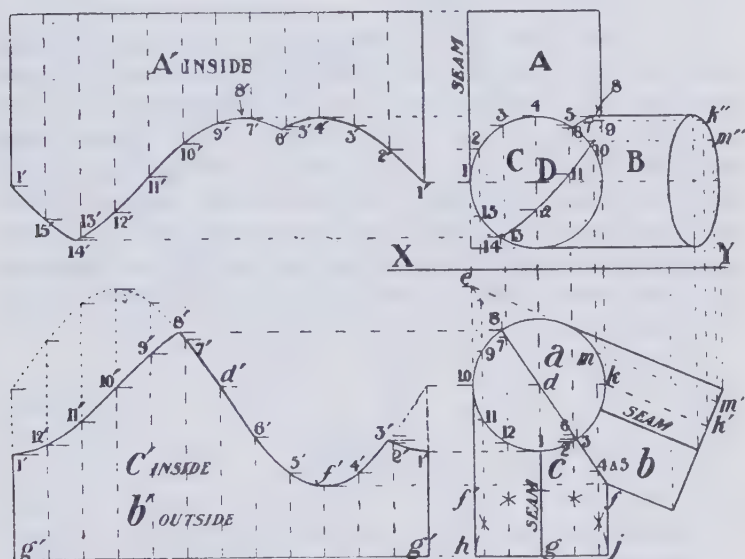


Fig. 94.

Let it be assumed the seam has to be on the line g 1, then taking the lengths of the lines in rotation as they are numbered, set them off in the development, and through them draw fair curves from $1'$ to $8'$, $8'$ to $3'$, and $3'$ to $1'$. The points $3'$ and $8'$ will not be on a division line, but will be found by drawing the curve, their correct heights from $g'g'$ having already been set out. The complete rake of ef is shown by the dotted portion, and the development will represent the inside of c , and the outside of b .

To develop the tube A , project the point 3 in the plan to the circle in the elevation in the point 6, and the point 8 to the circle

in the point 14, then project any number of points on the circle about d , such as k, m , to the end of b in $k'm'$, and from these to the elevation in $k''m''$, and again from these draw lines parallel to XY ; project k, m to the elevation till the lines drawn from $k''m''$ are cut in the points 9 and 10. By this means any number of points may be found through which trace an ellipse. The development may now be set out taking the points in rotation as they are shown in the figure.

Though the development is set out from the circle and ellipse in the elevation, they are really alike, and the lay-out could have been done from the circular portion commencing at 1, and taking the points in rotation to 6, then returning to the point 14 and returning again to the point 1, in fact the development may be set out from the plan alone by using the circular portion of a and taking the points in rotation from 10 to 3, then from 3 to 8, and again from 8 to 10, but the figure has been done in the above complete manner in order that the reader may be better able to understand it.

PROBLEM 60.

To find the connection lines for three tubes, the area of one to equal the combined areas of the others, and all to be in the same plane, but their centre lines not to meet in a common point.

Let A, B, and C, fig. 95, represent the tubes to be connected by the tubes D, E, and F. Produce their centre lines till they intersect as at G, H, and J, and from G and J as centres describe circles equal to the tubes A and B. Produce the sides of D tangent to the circle about G, and the sides of E tangent to the same circle. Join their intersections by K L. From the end of C draw side-lines tangent to the circle about J which will give the intersections at M L, join M L, the other side of F will meet the side of D in N; K being within the figure, the line K L will not be needed, but the connection between D and F must be a curve as N O L.

The connection lines will now be for the tube D, N O L; for E, the line M L, and for F the curve N O L, and the line M L.

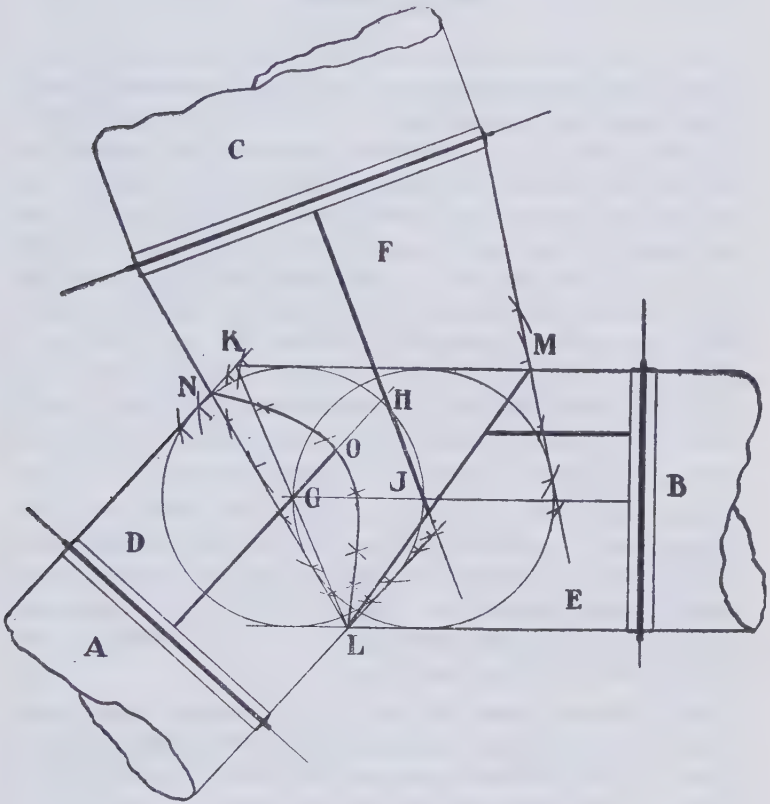


Fig.95.

Though this figure shows the point L as common to the three tubes it will not always be so, it depends on the position of the tubes A, B, and C, the desire being to have the connecting tubes continuous with those from which they are led. The development of D may be set out by Problem 45, page 50, the cone F by Problem 56, page 81, and the tube E by Problem 39, page 36.

PROBLEM 61.

To set out two conical connections between three parallel tubes of different diameters.

Let it be granted the centre lines of the tubes A,B, and C, fig. 96, if produced would meet at D. From D as centre describe a circle equal to the largest tube. Set off DE and DF equal to each other, and at any convenient position on the centre lines, Draw GH and JK at right angles to DE and DF, and draw the side lines of C tangent to the circle. From G. H. J, and K draw lines tangent to the circle producing the intersections at L.M.N, O,P,R. Join LM, NO, and PR intersecting at S, which will not be on the centre of the circle. The connecting lines for C will be LSN; those for the conical tube T will be PSN, and those for U will be PSL. One half the tube C has been developed in C', and the conical parts being alike are developed in T'. These may be set out by Problem 53 for the cones, and by Problem 39 for the tube C, using the rake height NM for the purpose.

This method will apply to any tubes, no matter what their diameters may be, and it is not necessary to have the circle at D of any particular diameter; so long as the side lines are drawn tangent to it the intersections when joined will give the lines forming the connection, the only condition in the problem is that the tubes shall be in the same plane.

The miniature shows the form of the connection when made up, and it always looks a very neat job, but when developing it is as well to keep the seams clear of each other in order to avoid having too many thicknesses at the joint holes.

PROBLEM 62.

To develop a Y connection of tubes equal in diameter meeting in a common centre, but one tube to be in a different plane to the others.

Let A,B, and C, fig. 97, represent a front elevation of the tubes, on the line XY, the centre lines meeting at the point D.

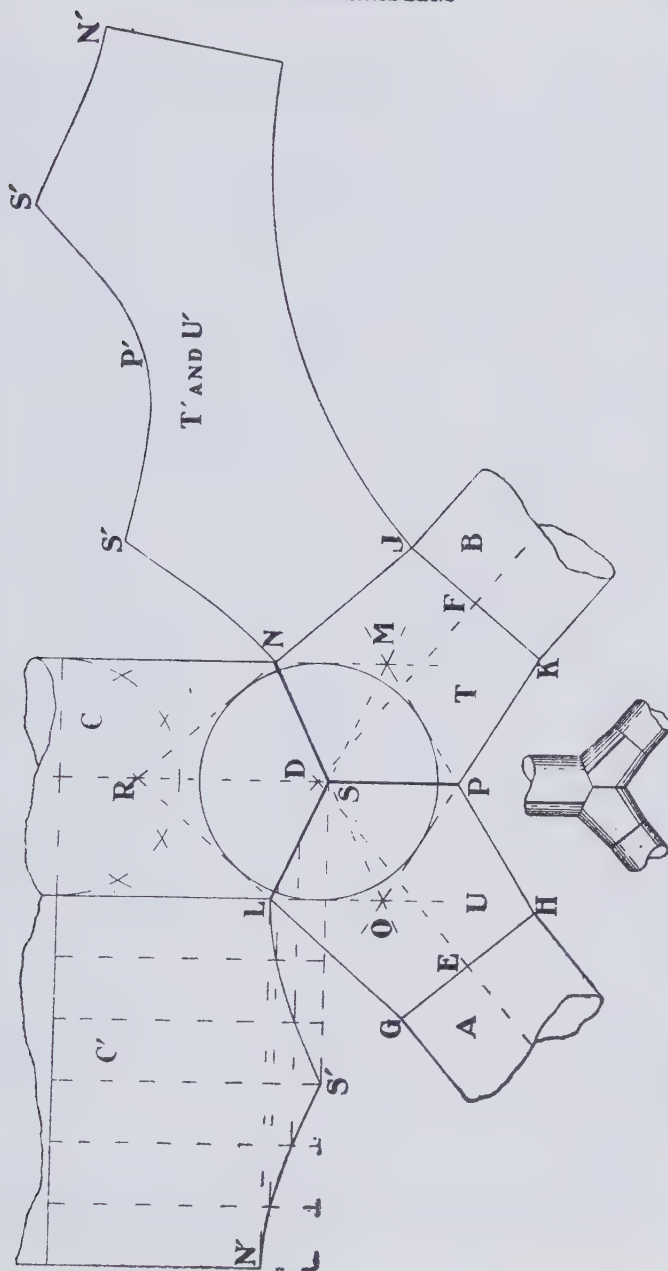
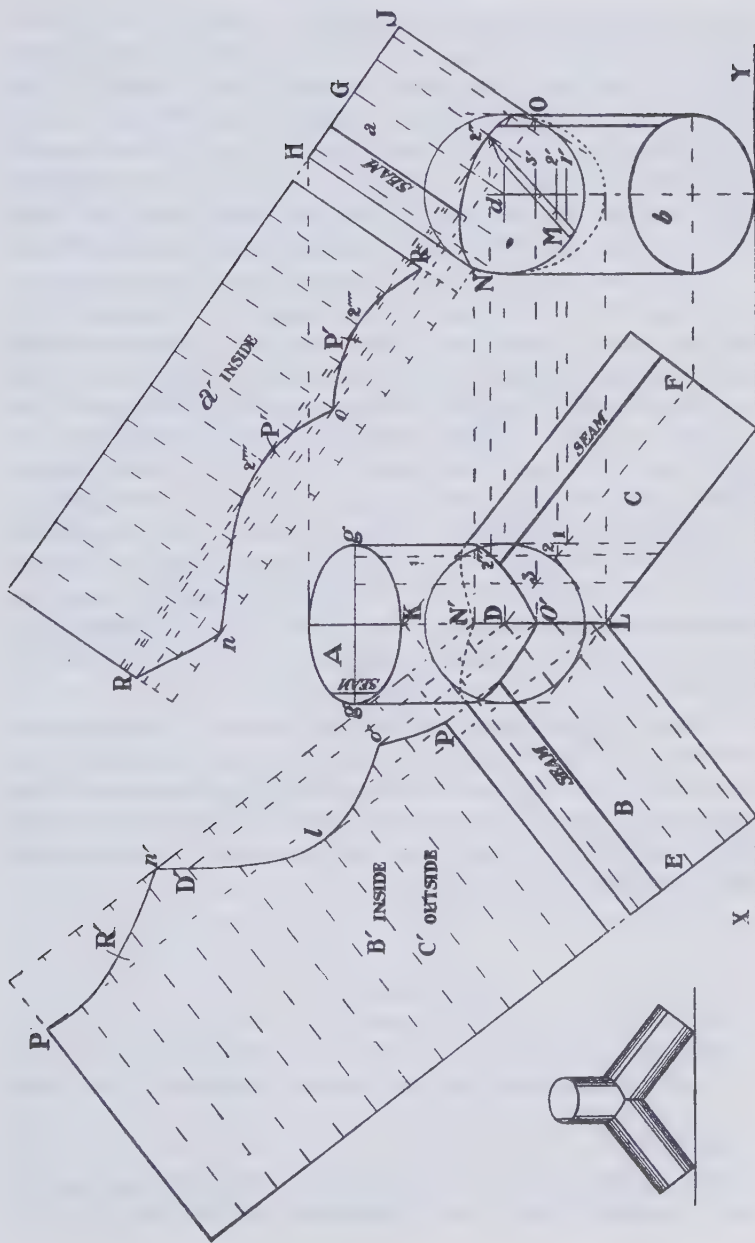


Fig. 96.

Set off from D the true lengths of B and C in E and F. Draw a side elevation in *a b* having the point *d* the same height above XY as D, and the centre line of *a* at the proper angle required. Set off from *d* the true length of *a*, in G. From D and *d* as centres, with radius equal to that of the tubes, describe circles, and draw the outline of the tubes by lines tangent to the circles, and parallel to their centre lines. Through G draw a diameter HJ; project G to *gg*, and divide HJ, and *gg* proportionally for projection (Prob. 39, fig. 48). From the points on HJ draw lines parallel to G *d*, and from the points on *gg* draw lines parallel to the centre line of A. The lines from *gg* must be produced till they cut the centre line of the tube C as at 1, 2, and 3. The tube C will now be cut in parallel elliptical sections which engage with the parallel sections of the tube A and where the sections intersect will be points on the line of connection. Project the points 1, 2, and 3 to the side view by the lines 1', 2', 3', the point D is already projected in *d*. The true size of the elliptical sections will be KL as a major axis, and the diameter of the tubes as a minor axis. Set off from one end of a straight-edge the half axes of the ellipse, and apply it to the centre line of *b* in conjunction with the lines 1', 2', 3', and the line through *d* in succession in the manner shown in the figure where it is applied to the centre line and line 2', the end of the straight-edge indicating on the corresponding line from HJ, a point which is on the line of connection. In this manner, any number of points may be found through which to trace the curve from N to O. It will be noticed the points N and O are not only on the ellipse having *d* as its centre, but is also on the side lines of *a*, the curve N O being elliptical. The development of *a* may now be set out, and commencing the lay-out from the seam line marked on *a* take the lengths of lines from HJ in rotation to O, then return to N, and back again to the seam line; this will give the curves from the seam line to *o*, passing through the point 2''', *o* to *n* passing through 2''', and *n* to the seam line.

Before developing the tubes B and C, it will be necessary to find the line of connection on the front elevation. Project all the points on the curve N O by lines drawn parallel to XY till



they cut their corresponding lines drawn from gg as at N' , O' , and $2''$; through these points draw the curves; these curves will be elliptical, and will meet on the line KL at N' and O' . The development of C will be set out from the seam line to O' , then to L , returning to N' , and then following the curve to the seam line passing through $2''$. B and C being alike, the development has been set out from C , the projections from the curve $N O$ not being carried to B in order to avoid confusion of lines.

When developing the tubes B and C , it will be necessary to divide the end of one tube proportionally for protection, and from the points obtained draw lines till they meet the curve $N' O'$, and the line of section KL between B and C , the portion of this line which enters into the development being $N'L$; set out $B' C'$ from these lines producing points through which three curves may be drawn—thus, seam line to o' , o' to n' passing through l and D' , and from n' to the seam line. After setting out the two developments cut the curve $n' P$ in R' using radius nR , and from o set off oP' equal to $o'P$, then the points P , R' , n' , o' will be the positions for holes in B' and C' which will engage with those on the development a' at P', R, n, o , the holes at n', l, o' in plate B' engaging with the same holes in plate C' , the plate C being marked off from B' after turning it over.

Though ellipses have been drawn at A and b , these are not necessary for the purposes of the problem, but they have been done with a view to giving the reader a better idea of the assembled tubes; the important point is to have the correct centre line lengths and angles set out in the two elevations. The miniature shows the tubes when complete.

PROBLEM 63.

To develop three tubes of equal diameter, whose centre lines meet in a common point, but the plan and elevation of one of the tubes to be at an angle to XY .

Fig. 98 is an elevation and plan of the proposed tubes, showing their connection lines, and is presented at this stage of the

problem in order to give the reader a clear conception of the nature of the finished connection. The tubes B and C are at different angles to the horizontal plane, but are parallel to the vertical plane, whilst the tube A is at an angle to both, as will be seen in the figure. It may here be pointed out that in any group of three tubes meeting at a common centre, any two of them may be regarded as in the same plane, because any two lines which meet are in one plane, and it therefore follows that

in a group of three tubes whose centres meet at a common point there are three sets of two tubes each, or, in other words, their centre lines go to form three planes intersecting at the point of common centre:—thus, if the centre lines ED, FD, and GD, be each considered as parts of triangular surfaces or planes, and they be completed by joining EF, FG, and EG, it will readily be seen that the three surfaces or planes meet at D. These triangular planes are shown in the plan where the line *fdg* not only

represents FD and DG, but also FG, the triangle FDG being parallel to the vertical plane. If then the connection as between B and C were required, it needs no explanation to show the proper line is a straight line through the intersections of their outlines and is simply a common elbow. And as it is already explained that any two of such tubes are in one plane, it will follow that by turning the figure till that plane is shown its full size the common elbow line may be found for them such as for A and B, but as the tube A is to be connected to both B and C, A will be in the two planes AB and AC, therefore it will be necessary to revolve the figure again till the plane of AC is shown full size, when the connection line for them will be a straight line as with

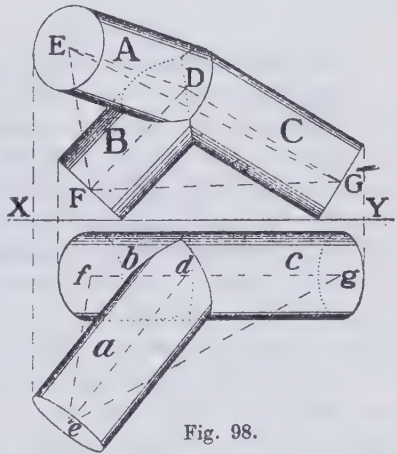


Fig. 98.

AB. There still remains the finding of the line of connection on B and C where A will engage, and for this it will be necessary to find the angle of revolution which one connection bears in relation to the other, thus, the line of longest length on the tube A for its connection with C will not be the same line for its longest length in relation to B, but must be some distance around the tube, and if that distance be found the various rakes may be set out by Problem 39, and the holes for the whole connection put in before rolling.

Let the elevation and plan of the centre lines of tubes A, B, and C, fig. 99, be represented by ED, FD, GD; and *ed*, *fd*, *gd*, respectively, the true lengths of the centre lines of B and C are shown in the elevation because the plan of them is parallel to XY, but the true length of ED is not shown because it is at an angle to both planes. At D, F, and G as centres, with radius equal to that of the tubes describe circles as shown, and draw in the outlines of B and C tangent to the circles and intersecting at H and J; join HJ which will be the line of connection as between B and C. Since A has to connect to B and C, the whole of HJ will not be required, but the longest length of B is JK, FK being at right angles to DF. The tube B has now to be revolved carrying A with it until A is in the vertical plane. Through E draw LE' at right angles to DF, then as the line DF is to represent a spindle on which the tubes are revolved, the point E will be somewhere on the line LE' since LE' is at right angles to DF. From *d* with radius *de* cut XY in *e'*, and from E draw a line EE'' parallel to XY, then project *e'* at right angles to XY till it meets EE'' in E'', a straight line from D to E'' will be the true length of DE, but E'DF will not be the true angle of A and B. To find the true angle, from D as centre and radius DE'' describe an arc E'' E' " cutting LE' in E'; join E'D, then E'DF will be the true angle and length of A and B. At E' describe a circle equal to that about D, and draw the tangent outlines intersecting those for B in M and N, join MN which will be the rake line as between A and B, the longest length of A being OM, and the shortest PN, the line OP being drawn through E' at right angles to E'D and

representing the end of A. We now have to find the angle through which the tubes have been revolved in order to find

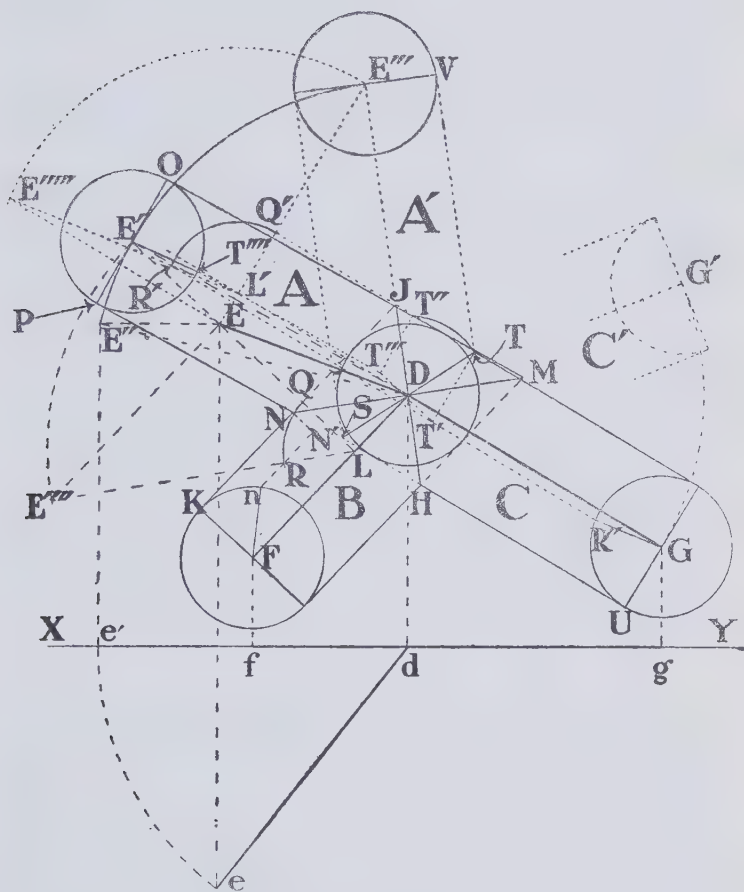


Fig. 99.

the relative positions for the two rakes MN, and HJ on the tube B. From L as centre and radius LE' draw an arc E'E'', and from E draw a line at right angles to EL cutting the arc E'E'' in E'' ;

join $E''L$, then from L with radius equal to that of the tube draw an arc QR cutting $E''L$ in R ; QR will be the angle of revolution. Through R draw $N'n$ parallel to DF till it cuts the circle about F in n , then the point N on A will engage with B on the line $N'n$, the point N' representing N revolved back through the angle QR . Kn will of course be equal to QR .

We now have to find the position of A in relation to C . Produce GD and from E draw a line at right angles to GD produced till it meets the arc $E'E''$ in E' and cuts GD produced in L' ; join $E'D$, then $E'DG$ will be the true angle and length of A and C . The fact that $E'D$ is on JH is but a coincidence in this drawing, they are not necessarily on the same line. About E'' describe the circle and draw the tangent outlines intersecting those for C in S and T ; join ST which will be the rake line as between A and C . Find the angle or revolution for A and C by describing an arc $E'E'''$ from L' as centre and radius $L'E''$, then from E draw a line at right angles to $E'E$ meeting the arc in E''' ; join $E'''L'$ and from L' with radius equal to that of the tube draw an arc $Q'R'$ cutting $E'''L'$ in R' , and $E'L'$ in Q' , then $Q'R'$ will be the angle of revolution as between the rake lines HJ and ST for the tube C . From R' draw a line parallel to DG till it cuts the circle about G in R'' , then $R''U$ will be the relative positions for the shortest lengths of tube, the point T on A' engaging with C on the line $R'R''$.

There still remains to be found the relative positions of the two rakes for the tube A , the rake lines being MN and ST . From T draw a line at right angles to DG till it meets $R'R''$ in T' , T' will be the position of T if the tubes C and A' were revolved back to their original positions with E'' at E , then as A has been revolved upon B we must find the position of T' when it is also revolved upon B from which the relative positions of MN and ST will be found on A . From D with radius DT draw an arc meeting MO in T'' , then from T' draw $T'T'''$ at right angles to DF , and from T'' draw $T''T'''$ at right angles to DE' producing the point T''' ; from T''' draw a line parallel to DE' meeting the circle about E' in T'''' , join $E'T''''$, then when developing A with the rake MN

the line VT will be distant OT'''' from OM, the angle of revolution being $O E' T''''$. This may be more clearly understood if the figure be imagined as being revolved in the following manner:— Suppose C to be revolved back to the first position with E''' at E, the point T will have been carried to T' , then if B be revolved carrying A with it till E is at E' , T' will be at T''' ; then assuming C to have been lifted as it were when B was revolved, and then turned down by revolving A till C is at C' , the point T will be at T'' , for the angle $E'DG'$ is the same as $E''' DG$.

It is well to set out the three tubes in separate figures showing the rakes with the angle of revolution for one in respect to the

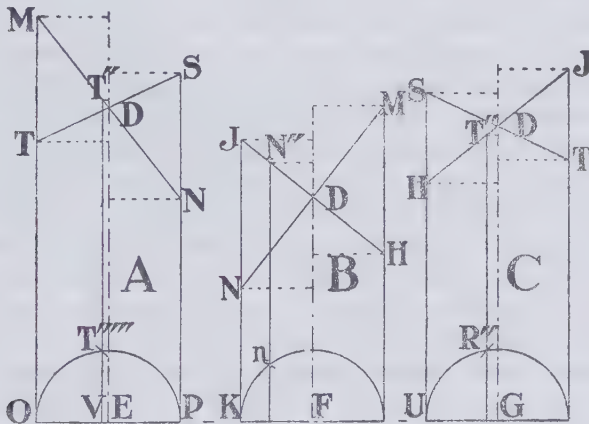


Fig. 100.

other. In fig. 100 the tubes A, B, and C are thus shown, and through the angular point T'''' on A a line is drawn to meet the rake line MN; this will be the line on which the lowest part of the rake ST commences, and by drawing the line to T'' a point on the rake MN will be found in T'' from which to draw the commencing line in the development for ST. B and C are treated similarly. The points NTT''S and M have been projected to the centre line of A from which the various heights are taken from the

base E for the purpose of applying Prob. 39, and similarly with B and C.

Fig. 101 shows the three tubes developed by applying Problem 39. Dealing with A first, the heights from the base of the tube are taken from Fig. 100, and set off on a straight line EM in NTDTSM, D being the centre point of both rakes, and T["] indicating the position where a line through the angle of revolution engages with the rake MN. From D as centre and radius DM describe a semi-circle MN and divide it into six equal parts; do the same with DS as radius. Strike a line EE at right angles to EM and set it off equal to the circumference of the tube. Divide EE into twelve equal parts and from each point draw a line parallel to EM, these are shown by heavy lines; from the points on the semi-circle MN draw lines at right angles to EM through the development, these are also shown heavy; now determine the position for the seam having regard to the development representing the inside of the tube, and draw in the curve through the intersections of the heavy lines, the rake curve will then be shown at M'N'. From T["] on EM draw a line at right angles to EM till it cuts the rake curve M'N' in T^{'''}; through T^{'''} draw the line T^{'''} V parallel to the adjacent division line, this will be the line on which the lowest point of the rake TS occurs. From T^{'''} V set off on the centre line drawn from D a new set of divisions, shown dotted, and from the points on the semi-circle ST draw lines, shown dotted, intersecting the new divisions, and through the intersections of these dotted lines draw the rake curve for ST which will cut the rake MN in two points where holes are to be marked as joint holes for the whole connection. Holes may now be marked on the points of intersection through which the rakes have been drawn, but as the joint hole at T on the development of C is so close to the hole marked on the intersections, the seam joint hole should be put in and the one next to it left out, and as the seam of C is to meet the rake ST on A near the point T, the holes at that part will need to be marked accordingly, so that on the development of A the hole at the intersections at T will not be put in, but a joint hole must be marked in near it according to the position of the corresponding

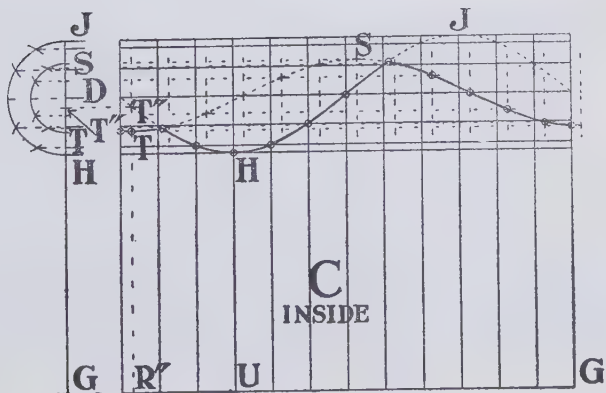
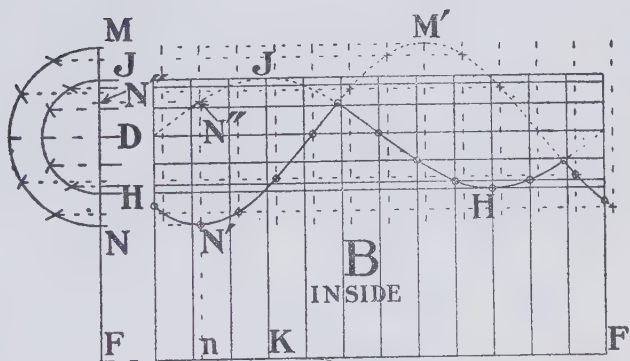
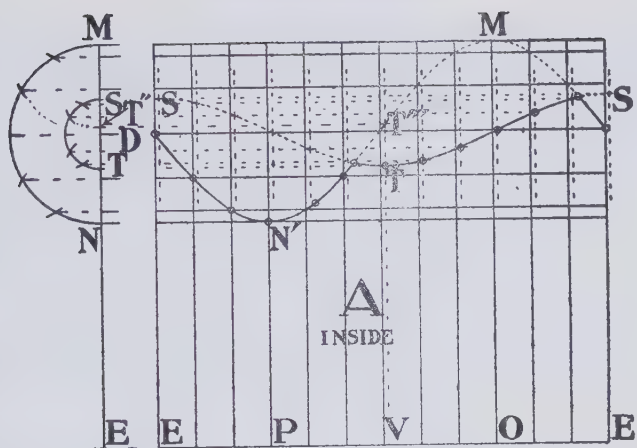


Fig. 101.

hole at T in the development of C. By carefully noting these positions for the joint holes all the holes for the connection may be put in before rolling up.

B and C have been developed in the same manner, the point N" on FM being projected to the rake line HJ from which is found the line for the lowest point of the rake M'N', the rake HJ being drawn in first. In the development of C the rake HJ is first drawn in, and the point T" on GJ projected to it in T" from which is drawn the line for the lowest point of the rake curve ST. It will be best to set out all the rake curves before marking in the holes then they can be marked with less risk of confusion.

The method explained in this problem is greatly different to that shown in Fig. 97 which has been done by taking parallel sections to find a line of interpenetration, but this method will apply to that problem also, and the different methods shown will be an advantage to the reader. To avoid complication the matter of thickness has not been dealt with in this problem, but it has been fully considered and explained in Problem 43. page 46, which should be read up.

PROBLEM 64.

To find the lines of connection for two tubes of equal diameter, and a conical tube, the centre lines meeting in a common point, and the conical tube to be at an angle to both planes.

Though there is in this problem much in common with Problem 63 there are differences which must be considered by reason of one tube being conical; the rakes for the two parallel tubes will cross on the centre point, but the others will not cross there, and further, the line for determining the angle of revolution for the rakes of the conical tube must be drawn from the apex of the cone.

In fig. 102 let ED, FD, and GD represent the elevation₃ of the centre lines of the tubes A,B, and C above the line XY, the tube A being conical, and at an angle to both planes, whilst B and C are parallel to the vertical plane. Their plan will be *ed*, *fd*, and *gd* respectively. About D, F, and G describe circles equal to the size of the tubes B and C, and draw in their tangent outlines intersecting

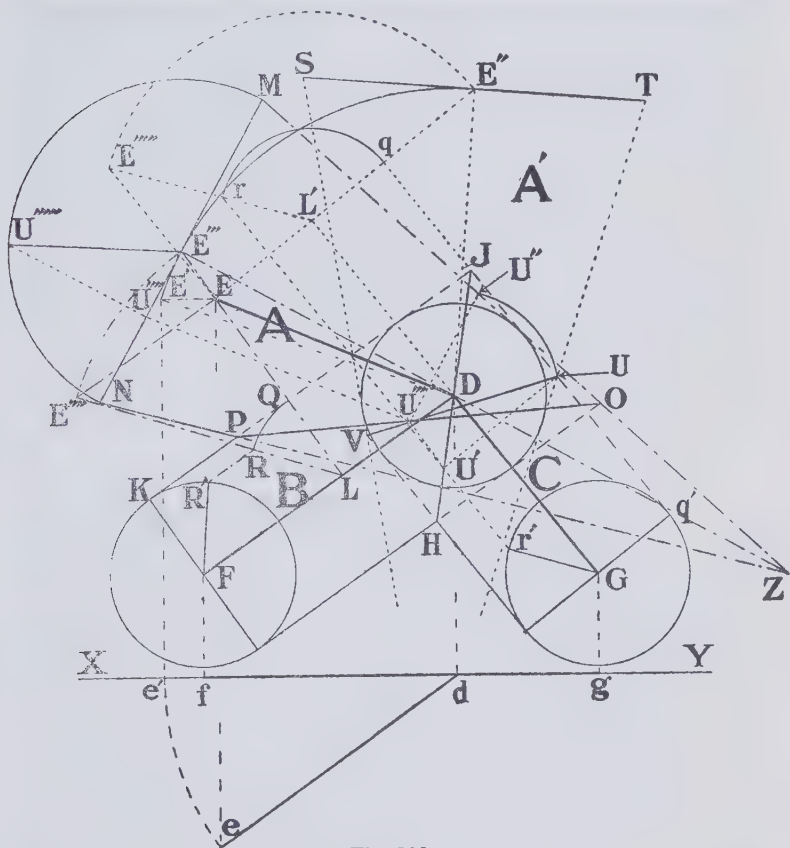


Fig. 102.

at H. and J; join HJ which will be the line of connection as between B and C, the longest length of B being KJ, the line FK having to be drawn at right angles to DF. From E draw EE' parallel enXY, and from *d* as centre draw the arc *ee'* with radius *de*. Project *e'* to the elevation at right angles to XY till it meets

EE' in E' . A line drawn from E' to D will be the true length of DE , but $E'DF$ will not be the true angle of EDF . To find the true angle, from D with radius DE' draw the arc $E'E''$, and through E draw LE''' at right angles to DF meeting the arc $E'E''$ in E''' ; join $E''D$, then $E''DF$ will be the true angle and length of the centre lines at A and B , A having been brought into the vertical plane by being revolved upon DF as a spindle. Through E'' draw MN at right angles to $E''D$, and set off $E''M$, and $E''N$ equal to the radius of the base of the conical tube A , and from M and N draw lines tangent to the circle about D meeting at Z and intersecting the outlines of B in O and P ; join OP which will be the line of connection as between A and B . From L as centre with radius LE''' draw an arc $E''E'''$, and from E draw a line at right angles to EL meeting the arc $E''E'''$ in E'''' ; join $E'''L$. From L with radius equal to that of the tube B draw the arc QR meeting $E'''L$ in R , and from R draw RR' parallel to DF meeting the circle about F in R' , then KFR' will be the angle of revolution through which A has been revolved with B , and the lowest position of the rake line OP on the tube B will be KR' from KJ .

The tube C has now to be revolved carrying A with it till A is in the vertical plane at A' . Produce GD to L' and from E draw EE'' at right angles to GD produced meeting the arc $E'E''$ in E'' , and intersecting GD produced in L' . Join $E''D$, then $E''DG$ will be the true angle and length of EDG . Through E'' draw ST at right angles to $E''D$, and set them off from E'' equal to M and N from E'' . From S and T draw lines tangent to the circle about D intersecting the outlines of C in U and V ; join UV which will be the line of connection as between A and C . From L' with radius $L'E''$ draw the arc $E''E''''$, and from E draw EE'''' at right angles to EE'' ; join $E''''L'$, and from L' with radius equal to that of the tube C draw the arc qr meeting $E''''L'$ in r , then qr will be the angle of revolution through which A has been carried to A' . From r draw a line parallel to $L'G$ meeting the circle about G in r' , then rr' will be the line on C where the lowest point of rake UV commences, the angle of revolution being $q'r'$.

The position of UV in relation to OP for the tube A has now to be determined. From U draw a line at right angles to DG

till it meets rr' in U' , this will indicate the position of U when it is revolved back to its first position with E'' at E . From D with radius DU draw an arc UU'' meeting MO in U'' , this will indicate the position of U if A' and C were revolved on the point D as a centre till E'' is at E''' . From U' draw $U'U'''$ at right angles to DF , which will be equal to revolving U from its second position in U' , then its position must be somewhere on $U'U'''$, and a line drawn from U'' at right angles to $E''D$ will meet $U'U'''$ in U''' which will be the position of U in relation to OP . From Z draw a line through U''' till it meets MN in U'''' , and from U''' draw $U'''U''''$ at right angles to MN meeting the semi-circle MN in U'''' , then the angle of revolution for UV in relation to MN will be $U''''E''M$.

Fig. 103 shows the three tubes set out with their rake lines and angles of revolution, and when developing A the rake OP will be set out first with the line $U'''U'$ as the line in the develop-

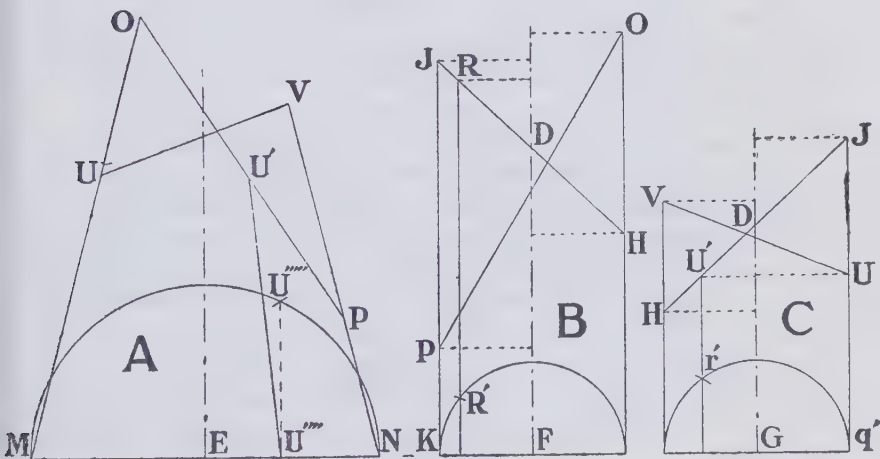


Fig. 103.

ment upon which the lowest point U of UV occurs, and is dealt with as the next problem. The tubes B and C are set out showing their rake lines and angles of revolution in R' and r' , the points

of rake height being carried to the centre line for the purpose of applying Problem 39, then the point P will occur on the line R'R, and the point U will occur on the line r'U'.

For the development of B set off on FO, fig. 104, the points P, H, D, R, J, and O equal to their spacings found on the centre

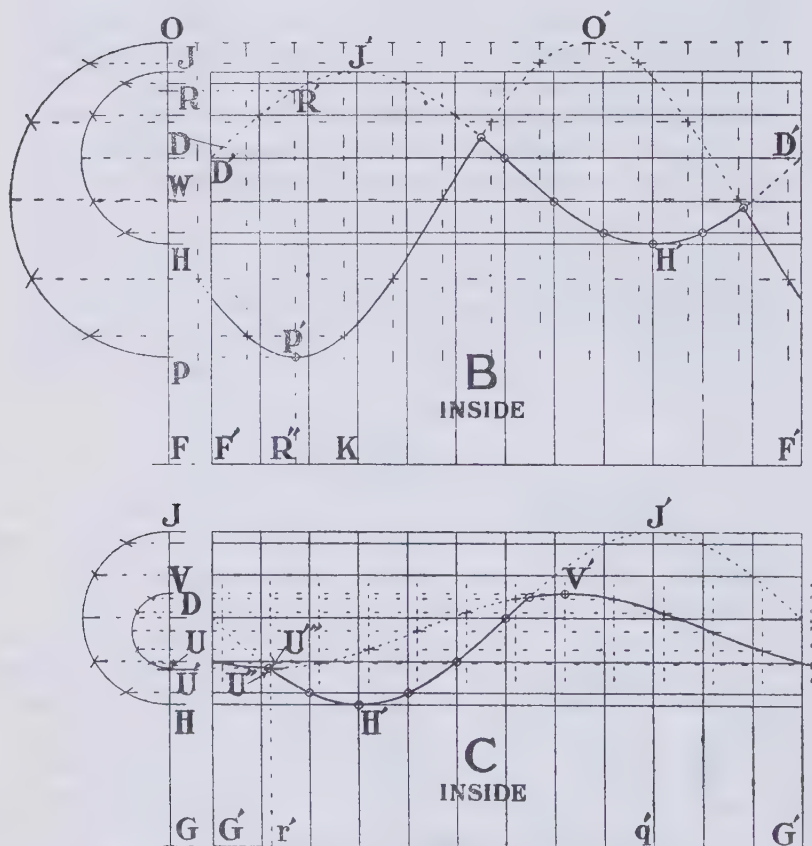


Fig. 104.

line of B in fig. 103. D will be the centre of the rake HJ but not the centre of rake OP, this will have to be found by bisecting OP in W. Set off first the rake HJ. From D as centre describe a semi-circle HJ and divide it into six equal parts as shown.

Strike a line $F'F'$ at right angles to FO and make it equal to the circumference of the tube B ; divide $F'F'$ into twelve equal parts, and at each point draw a line parallel to FO . From the divisions on the semi-circle HJ draw lines parallel to $F'F'$ intersecting those already drawn in the development; these lines are shown heavy. Let it be assumed the seam is to be on the line FD , fig. 102, then the rake curve will commence at D' and continue through the intersections as shown giving the curve $D'J'H'D'$. From R on FO draw a line parallel to $F'F'$ till it meets the rake curve $H'J'$ in R' , then from R' draw a line $R'R''$ parallel to FO ; this will be the line on which the lowest point of the rake OP occurs. From $R'R''$ set off on $D'D'$ a new set of divisions equal to those on $F'F'$, and through them draw short lines, shown dotted. From W with radius WO describe the semi-circle OP and divide it into six equal parts, then from these points draw lines to the development till they intersect the dotted lines already drawn, giving the intersections through which to draw the rake curve $P'O'$ commencing at P' as the lowest point on $R'R''$. If the space $R''K$ be measured it will be found to equal $R'K$ measured along the arc in fig. 102. The two rake curves having been drawn in they will be found to cross each other in two points which are the junctions for the whole connection; at these points mark holes, and the dotted portions of the rake curves are to be cleaned off as they will not be required further. On the points of intersection for $H'J'$ holes may be marked, and a hole at P' . The reason more holes are not marked on the intersections of $O'P'$ is because that curve has to meet the curve cut from the cone and the intersections for the cone will not meet those for the parallel tube, but as the holes in the conical tube are to be put in after rolling to shape and fitting up, the holes may be spaced along the curve $P'O'$ as required, the hole at P' and those at the junction of the rakes serving as a guide when fitting together.

The tube C has been developed in a similar manner, and holes put in for the curve $H'J'$ to meet those along $H'J'$ in B . The hole marked at V' will engage with a hole in the conical tube. The rake $H'J'$ is first drawn in, then the point U' projected to the curve in U'' through which is drawn the line $U''r'$. The

the points on OP draw lines at right angles to the centre line of the cone EZ till they meet the side NZ. From Z with radius ZN draw the arc 4'4' and make it equal in length to the circumference of the base MN, then divide it into twelve equal parts as 4', 5', N', &c., marked around the outside of the arc from left to right; join all these points to Z. From Z with radius ZP draw an arc, and similarly from each point on ZN projected from OP, these are shown by heavy arcs, then through the intersections of the straight lines and arcs draw the rake curve P'O'.

Project U' to ZN, and from Z with that point on ZN as radius draw an arc cutting the rake curve P'O' in U"; through U" draw a line from Z meeting the base arc in M", this will be the line for the lowest point of the rake UV. From M" set off along the base arc a new set of divisions as 1", 2", E", &c., on the inside of the arc, and from these points draw short lines towards Z, shown dotted. Project the points on UV to the side of the cone MZ at right angles to its centre line, and from Z with radii to these points draw arcs cutting the straight dotted lines already drawn in a series of points through which to draw the rake curve V'; its lowest point is too close to U to be marked by a letter in this drawing. Where the two rakes intersect will be the junctions to correspond with those on B and C in fig. 104. Holes may be marked at the junction of the rakes, and also at P'V' to engage with those in B and C in the previous problem, the remainder being put in after the tubes have been flanged and adjusted to each other.

PROBLEM 66.

The connections for four tubes of equal diameter by an application of Problem 39, fig. 48.

Sometimes tubes have to be connected, which, by reason of their position almost, if not quite, prevents the application of the

true Y form of connection, and other means have to be devised to achieve the result aimed at. Naturally the first consideration in such a case, as in fact with all problems, is simplicity consistent with the conditions present in the problem. An instance of this is given in fig. 106, where the tubes A, B and C are of equal diameter in the same plane, and so disposed that to make a proper Y connection is almost out of the question. There can be no more simple method of making the connection than by an application of Problem 39 in conjunction with Problem 44, and for this purpose produce the centre lines of A and B equally in D and E, and from D and E as centres describe circles equal to the tubes; draw the tangent outlines giving the intersections at GH, JK; join DE, and to it produce the centre line of tube C in F. Produce the outlines of C till they intersect GK at L and M; join LF and MF, then LFM should be a right angle. Project H to H' at right angles to the centre line giving H'G as the rake height by which to set out the development in W'. The same rake height serves for the development of X in X', but the seam having to be so placed as to clear the connection of the tube Z its position will be on the first division from the centre line DE as at NO, the developed curve being N'G''H''N'. The lower curve of X' is obtained from JK by projecting K to K' at right angles to DE, giving K'J as the rake height, the developed curve being O'E'K' E'J'O'. The hole in X' will have for its centre line the line G''K'' and will be set out on the same division lines in the development by projecting F to GK in F', giving F'M as half a rake height, and F'L as another half rake height from which the curves F''M'F'', and F''L'F'' are obtained. The development of Y will be set out from K'J as the rake height. The tube Z will be developed by projecting M to M'', and L to L'', giving half rake heights in M''F, and L''F, the development producing the curves F'''L'''F''' M'''F''''. The whole of these figures may be set out by Problem 39, the question of thickness affecting the rake heights being dealt with in Problem 43, which should be read up.

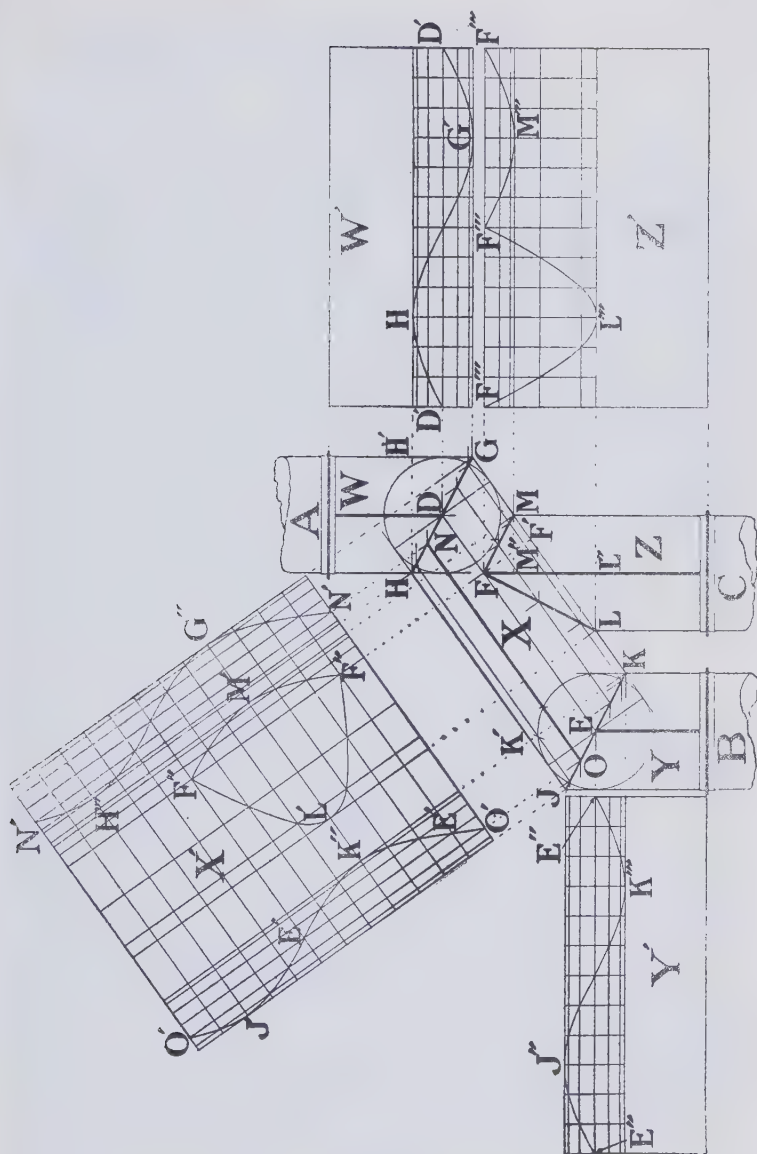


Fig. 106.

MISCELLANEOUS PROBLEMS, INCLUDING DEVELOPMENT
BY TRIANGLES.

Probably the foregoing development problems will be found sufficiently extensive so far as straight or parallel tubes and cones are concerned, but the variety of connections that may be devised and are met with in the course of a Boilermaker's experience is so great that it would be almost impossible to set out every conceivable form of connection in the shape of definite problems, the reader is therefore expected to apply such figures as lend themselves to the work he may have in hand, and there will be little difficulty in finding one or more which may be applied to his work, for problems are not intended to represent a definite figure so much as to illustrate a principle by which figures of that character may be set out, and it is this ability to apply knowledge which marks out a workman as a man of resourcefulness, and enables him to overcome difficulties which to one less endowed would be insurmountable.

While cylinders and cones occupy a large field in the subject of developments, they do not by any means cover the whole ground; there are numerous figures which have to be set out by other means, such as by a series of surface triangles, usually termed triangulation, wooden templates, and even iron gauges constructed to form a skeleton of the figure, the latter being used mostly where the contour of the plate demands the application of a complete gauge in the process of setting to shape, but where the figure is of that form which contains straight lines for bending or rolling the skeleton gauge will rarely, if ever, be needed, and where such rolling lines meet at a common point if produced, the figure may be set out by a series of arcs of varying radii through which the required outline of the development is to be drawn. An instance of this is given in the next problem.

PROBLEM 67.

To develop a raked bonnet or cape for a main funnel, the edge to be the same distance away from the funnel all around.

Fig. 107 is an illustration of the bonnet fitted to a funnel by means of the flange, the top and bottom edges being parallel, and the bottom edge the same distance from the funnel at all parts, then as the bonnet is raked to the funnel a plan when viewed parallel to the centre line of the funnel will be two concentric circles, one for the flanged edge, and one for the outer edge. Sometimes this figure is developed by producing the sides of the bonnet till they meet at a point, and treating the figure as part of a regular cone, and while this will give an almost correct shape to the lay-out, it can hardly be called true because the rake of the figure produces an ellipse from the cone instead of the circle which it has to assume when finished, and though the difference is not great it is as well to set out the development by the accurate method. Producing the sides till they meet and then treating the figure as the frustum of a cone is quite correct when the bonnet is fitted to the funnel without rake.

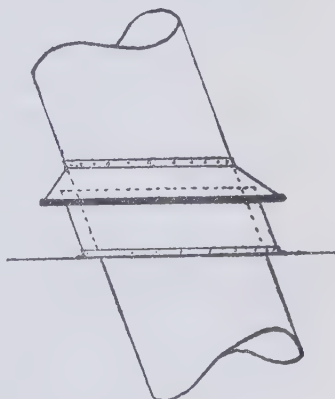


Fig. 107.

Draw the centre line of the funnel AB at right angles to XY, fig. 108, intersecting XY in C. From C as centre describe the semi-circles DE, FG, and with radius CG divide the semi-circle FG into six equal parts; from the points obtained draw lines towards C till they cut the semi-circle DE. From D and E draw lines DH, EJ parallel to AC, and connect them by the line KL which is to be the top of the bonnet at the required rake. Draw MN parallel to KL and at the proper distance from it, and project the points F, G to MN parallel to AC. The lines MKLN will be

on MN parallel to XY, and those on KL to LJ parallel to XY, then lines drawn from O to the points on NP will pass through their corresponding points on LJ, and each line will be the true length of those in the plan—thus, the line 22 is a plan of 2'2", and the line 2"2" is its true length, and its distance from O is also true. Though the semi-circles represent a plan of the figure they do not show the true perimeter, this must be obtained from an ellipse the major axis of which is MN, and the minor axis FG. Set off the half minor axis from B', the centre of MN, at right angles to MN in B'', and by Problem 28, fig. 31, draw the quarter ellipse NB'' to which project the points 3'4' parallel to B'B'' in 3"4". Draw any line OR, and from O with radius ON cut OR in N', and again with radius OL cut OR in L'. Take each point from N on NP in succession, and from O as centre describe arcs as shown at 2' " on the outer curve, repeat the operation from each point on LJ. Bend a strip of wood to the elliptic curve, and on it take the points N, 4", 3", B'', then set the point N on the strip fair to N' and bend it till each point engages with an arc in succession and the strip takes a fair curve which will give three divisions of the outer curve of the development in 4' ", 3' ", B' ", reverse the strip and continue the operation through the arcs 2' ", 1' ", to M'. Join all the points on the outer curve to O and set off on these lines the true lengths as 2"2" in 2' "2' " through which trace the inner curve to complete the development of half the bonnet plate. This method of taking the points from the ellipse on to a strip is more accurate than taking N4" as a radius and setting it off from N' to 4'" as the difference in the curves will make a difference with each successive stepping, and the result will be a slightly inaccurate curve and length. The straight lines on the development are rolling lines, and the amount of flange required must be added to the inner curve.

We have thought it well to detail this figure fully in order that it may be thoroughly understood, but to show how simple the problem is we will now explain how little detail is required. Draw the centre line AC, and the side line EJ parallel to AC. Draw GP parallel to AC and distant from EJ equal to the amount the edge of the bonnet has to be from the funnel. Draw NL

at the required bevel at the forward part of the funnel, and produce it to the centre line in O. From N draw NB' at the proper rake, and draw the quarter ellipse. Divide B'N proportionally for projection (Prob. 39, fig. 48), and project the points obtained to the ellipse. Set off LS equal to the full rake, and through S draw a line from O till it meets NP in S'. Divide NS' proportionally for projection, and from these points draw lines to O. The problem may now be completed as previously explained. By this it will be seen a plan is not needed, and half the elevation is also dispensed with. It may be pointed out that the bevels for flanging are those in the elevation as J2"2", which is the bevel for the flange at that part of the development corresponding with the numbers.

It is usual to fit a moulding to the edge of such figures, and this must be bent on edge to the shape of the outside curve of the development before being bent up to its position on the rolled plates.

PROBLEM 68.

To make a dished bonnet for a main funnel.

Probably there are few things about a steamer that look better than a well made dished bonnet to the funnel, and if the instructions here given be followed closely the resulting job will be all that can be desired. The usual size for such figures is to have the depth the same as the distance away from the funnel, and the sectional form to be a quadrant from the edge of the angle ring to the moulding. We will suppose there are to be six plates in the bonnet, the first thing to be done is to lay out the template for the plates, which is done as follows :—

Strike a line AB to represent the centre line of the funnel, and the line CD half its diameter from AB. At any convenient place on CD set out the sectional view of the proposed bonnet in

EFG, join EG, and produce it to the centre line in H. Bisect EG in J and draw JF at right angles to EG, bisect JF in K and through K draw a line parallel to HG in LG'. Measure along the curve the distance from F to G, and set it off from K to G';

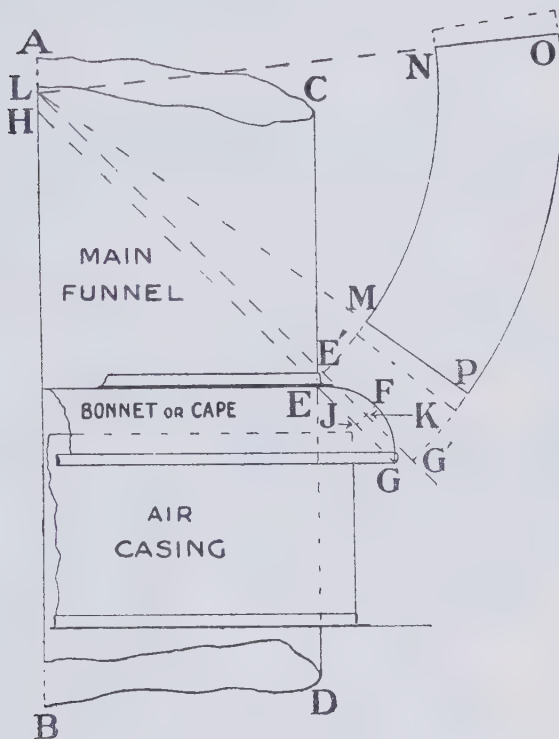


Fig. 109.

measure from F to E along the curve and set it off from K in E', then from L as centre and radius LE' describe an arc E'N, and from the same centre and radius LG' describe another arc G'O. Set off on the arc E'N the distance MN equal to one-sixth the circumference of the funnel, and from L draw lines through M and N till they meet the arc G'O in P and O, then MNOP will

be the size of the plate if no account were to be taken of any stretching or gathering in the process of setting to shape, but as this is considerable it is necessary to have the plate a little longer than the size shown in MNOP, and the amount to be added at each end had better be about three inches, this will be found sufficient. Cut out the six plates to the enlarged size, and proceed to set them to shape in a block cast for the purpose, before putting in any holes.

Fig. 110 shows in elevation, plan, and section, the shape of the block, the elevation being the position it is to be on the slab when in use, the bottom edge being kept close against two pegs, and the plate when heated is to be laid in the block so that the inner curve also rests against the pegs, then, by applying a wooden mallet on which blows are to be struck, the plate may be set to the shape of the block. Care must be taken to keep the buckles out as the plate is being dished, and while the middle has to stretch considerably, the outer and inner curves will be found

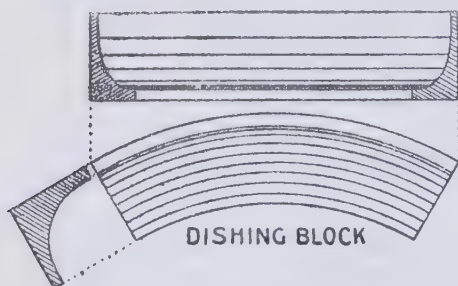


Fig. 110.

to gather up, the plate being of light material it buckles badly at the edges, and it is this buckling which has to be prevented, as much as possible, but with the plate well hot it will be found an easy matter.

The ends of the plate do not stretch or buckle much, they tend to simply bend, and it is this difference in the working which makes it such a difficult matter to set out the true butts, besides which there is the variation of heat, and the speed the plate is set to shape.

Though it is not altogether within our province, we desire to make a passing reference to the making of the dishing block as it is sometimes regarded as a large order for this kind of work, but the making of such a block involves so little trouble that there cannot be much to justify not having one. Instead of

making a complete pattern, all that is necessary is to make a mould from the sectional view, and attach it to a radial staff at the required radius, and by applying it to the sand in an inverted position the radial staff may be made to shape the sand to the size of the block, the mould being open at the top which is the bottom of the block when in use, from this it will be seen the position of the casting when in the sand will be an inverted view of the elevation in fig. 110. We have had several blocks made in this manner, and they have been quite satisfactory.

When the plates are set to shape, it will be found there is rather more plate at the middle of the outer curve than is required,

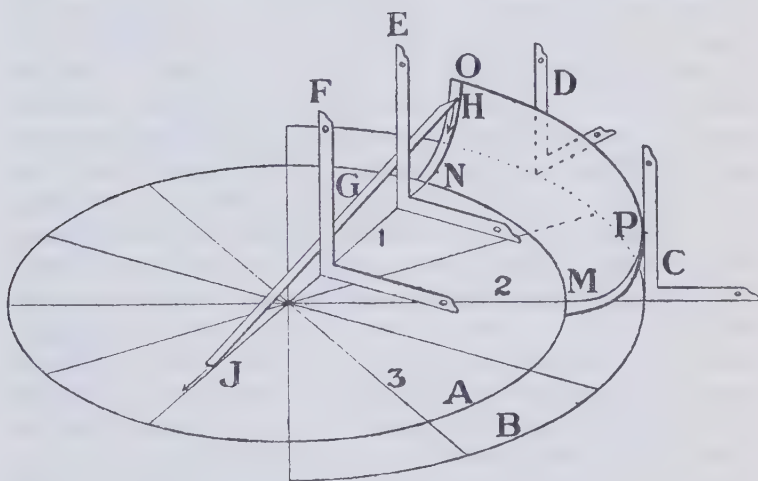


Fig. 111.

this is due to the stretching, but it need not be sheared off till the butts and holes are marked. To mark off the butts, describe two circles from the same centre as A and B, fig. 111, which is a view at an angle of 30 degrees to the horizontal plane, A being equal to the size of the funnel, and B equal to the outer size of the bonnet. Divide A into the same number of equal parts as there are to be plates in the bonnet, and draw the diameter lines

as shown at 1, 2, and 3. Apply a plate to the circle A, putting its inner edge fair to the circle, and apply a square to the outside circle as shown at C and D, so that the outer edge of the plate shall be fair to the square when the heel of the square is fair to the circle B. Having set the plate to its proper position dog it down to the inner edge. Procure two squares, and apply them as shown at E and F with their heels fair to the line 1, and their lower blades at right angles to it, the squares must be held as upright as possible, and a straight-edge applied to them as shown at G where the point H touches the plate and the end J is fair to the line 1, then by sliding the straight-edge along, as indicated by the arrows, keeping it close to the squares the while, the end H will trace the true butt line for that end of the plate in NO, repeat the process from the line 2 to get the butt line PM. The height of the plate may be set off with the square C. The butt straps should be punched before being set to shape, and they should be set aside a plate on the block, they may then be marked on to the plates during the process of setting out the butt lines; mark in the holes for the moulding, and punch all butt holes and moulding holes, and also shear off what may be necessary from the edge. The plates may now be assembled on the slab with their butt straps, this done, clip the moulding to the plates and mark it off; it will be found better to bend the moulding before punching because were it punched before bending it would bend in a series of flat places from hole to hole. Have the butts of the moulding just a little from two opposite butts of plate in order that the finished bonnet may be taken apart in halves to fix in position. The bonnet being now ready for rivetting, the holes for the angle ring are required. Make a template off the ring, taking care to mark the position it is desired to have the joint of the bonnet, this done, turn the bonnet over and mark off the ring holes, the bonnet may now be taken apart at the two joints, and the ring holes punched, when it will be ready for fixing in position. We have made a good many such bonnets, and have always found this method to produce an excellent job, and while the butts of the plates may be set out very nearly before setting, it is not worth while doing on account of the treatment

the plate has to undergo, the variation in heat, and the speed with which it is set to shape contributing to vary the final result as between one plate and another.

PROBLEM 69.

To make a direct connection between two circular tubes of equal diameter.

Let A and B, fig. 112, represent the two tubes to be connected, their termination CD and EF being parallel. Divide CD and EF proportionally for projection, Problem 39, fig. 48, and join

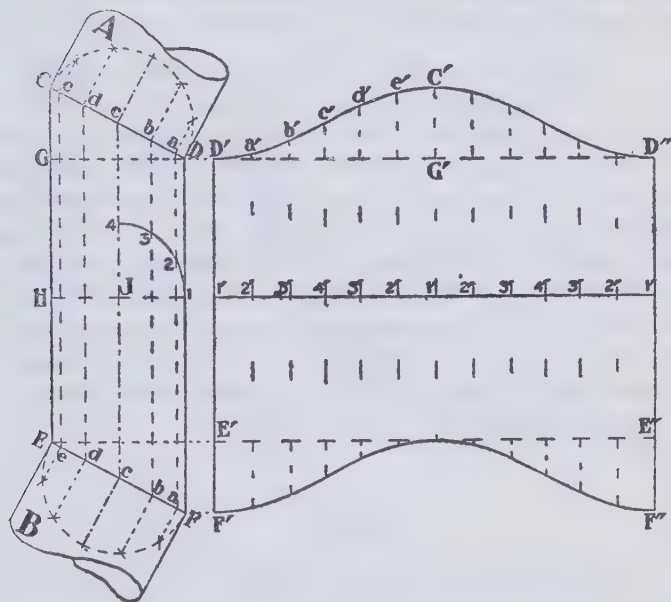


Fig. 112.

the points obtained, as by lines aa, bb, &c. At any convenient part of the connection draw a line H1 at right angles to cc, and from J set off J4 equal to Dc, then with J4 and J1 as half major and minor axes draw the quarter ellipse 4 3 2 1. The ellipse,

if completed, will be the section of the connection, and the ends have to be set out in the form of elbows to an elliptical tube.

To lay out the development draw any straight line $1'1'$, and on it set off the same divisions as are found on the elliptic curve, as $1', 2', 3', 4'$, repeating them in the reverse order to $1'$, in this manner all the divisions on $1'1'$ may be set off from a measurement along the curve from 1 to 4 taking the points 2 and 3, it will at the same time, give the circumference or perimeter of the tube in $1'1'$. Draw the lines $D'F'$ and $D''F''$ through $1'1'$, and at right angles to it, and through the points $2'3'$, &c., draw lines parallel to $D'F'$. From $1'2'$, &c., set off the points a', b' , &c., equal to their respective distances from H1, and through these points draw a fair curve $D'C'D''$. The curve for the other end may be set off in a like manner to complete the development.

By dividing CD and EF proportionally for projection the divisions on the elliptic curve are not equal, therefore those on the line $1'1'$ are not equal, but if preferred the centre line cc may be drawn and the ellipse set out as before, and then the ellipse divided into any number of equal parts, and lines drawn from these points on the ellipse to CD and EF will give the projection lengths from DG; in this way the development may be set out in equal divisions as with the ellipse, and the heights of the lines taken from DG. The curves will be exactly the same as by the first process, but the advantage of the first is that the points on the curve may be used as centres of holes to meet holes in the tubes A and B which are pitched off equally.

PROBLEM 70.

To set out the template for a radial tube, made up of tapering courses.

Let AB and A'B', fig. 113, represent the mean section of the tube between the larger and smaller ends of each course, the inner radius at that part being CB. From C' on XY as centre, and with radius from C to the centre of the thickness at B describe

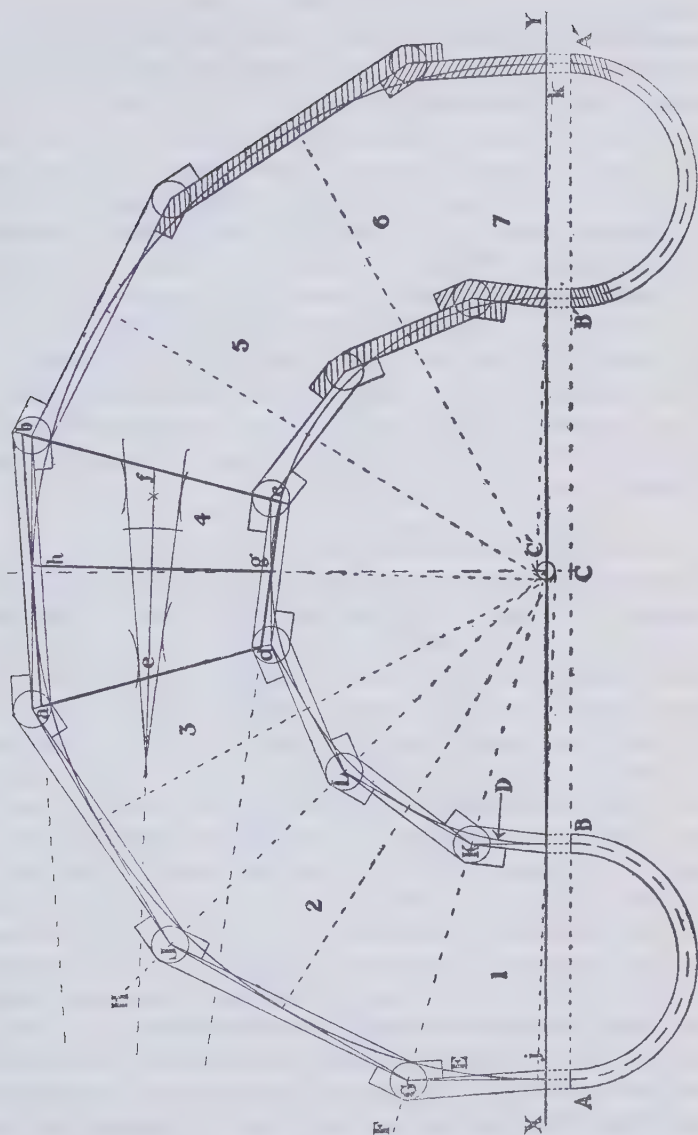


Fig. 113

a semi-circle D, and from the same centre with radius from C to the centre of the thickness at A describe another semi-circle E. As we propose having five whole courses and two half-courses, which is equal to twelve halves, divide the semi-circle E into twelve equal parts and through the first division draw the line C'F. From the centre of the thickness at A draw a line at right angles to XY till it meets the line C'F in G. From G describe a circle with radius equal to the thickness of plate. Through the third division on the semi-circle E draw a line C'H, and from the centre of the small circle G draw a line tangent to E till it meets C'H at J. About J describe a circle equal to that about G. Repeat the operation on the semi-circle D to obtain the points K and L, about which describe small circles as at G and J. In this manner the other small circles may be described and to them lines are to be drawn to represent the full thickness of iron as shown in section for the courses 6 and 7.

Having set out the figure showing the full thickness of iron it will now be necessary to deal with one course for laying out the template. We will take course number 4. Draw in the lines showing the centre of thickness *ab*, and *cd*, the ends of which are at the centre of the bend of the material; join *bc*, and *ad*. The lines *ba*, *cd* would meet if produced, but as the apex of the cone is so far away, the angle they form must be bisected by Problem 11, giving the centre line *ef*. From the point *g*, which is on the polygon line midway between the centres of the circles at *d* and *c*, draw a line *gh* at right angles to *ef*; if *hg* be produced, it will be found to be tangent to a circle described about C' equal to the thickness of iron in diameter, and the section of course 4 on that line will be a circle. The lines *a*, *b*, *c*, *d*; *e f*; and *g h* are the ones to be used in developing the course which will be the same for those numbered 2, 3, 5 and 6. The dotted lines *j* and *k* above and below XY on courses 1 and 7 show the amount of rake which has to be put in these in order that the ends of the tube shall be level, course 1 being raked long, and course 7 being raked short, and these rakes will produce ends slightly elliptical, but the difference from a circle will be so small that it will be imperceptible.

Figure 114 is a copy of the lines of plate 4 which are to be used for the development. The cone is extended by producing cd to j and setting off gj equal to ha . The lines aj and hg are divided proportionally for projection, and through the points obtained

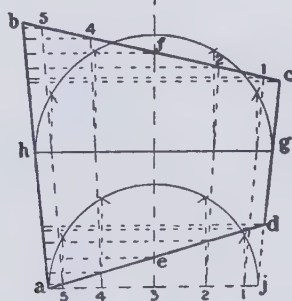
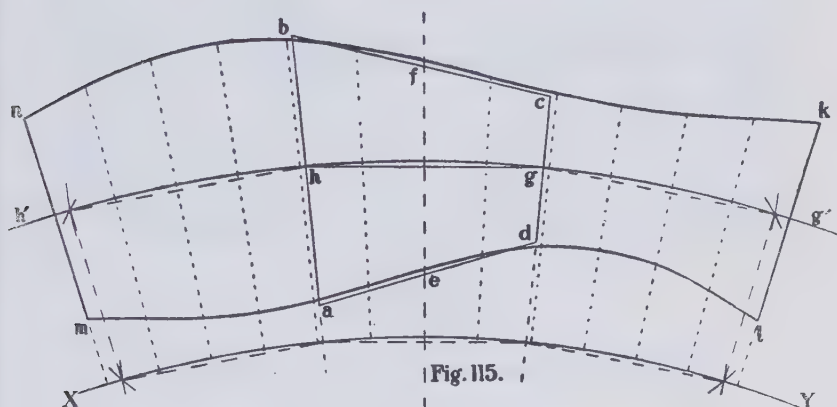


Fig. 114.

lines are drawn as 11, 22, 3f, 44, 55. It is not essential that the extension of the cone shall terminate at the point a , it may be continued any distance, and in the development, fig. 115, the cone has been so extended giving the arc XY , but the arc to develop from is $h'g'$, the length of which must be calculated from hg , fig. 114, the development being set out by applying Problem 54, page 77. It will be noticed the seams are so disposed that

there will be a minimum of thicknesses at the joints, and no distortion of the ends of the side seams when flanging; and as the template is to represent the inside of course 4 with the seam kl outside, it will represent the outside of courses 3 and 5 and so on alternately; the corner l will require to be thinned, and also the opposite corner at n for course 4, but the corners k and m will be thinned for courses 3 and 5. The points through which the developed curves have been drawn may be used as centres of holes in the same manner as in an ordinary elbow for parallel tubes, and courses 1 and 7 may also be marked off the same template, the arc $h'g'$ being the base in each case with the slight rake added for course 1 and deducted for course 7. The figure shows the thickness greatly exaggerated for the purpose of explanation.

PROBLEM 71.

To lay out a helical plate, and show its position on a tube.

The helix is more commonly known as a spiral, and it is the line on a cylinder which would be traced by an object touching the surface and travelling at a uniform speed parallel to the axis while the cylinder is revolving at a uniform speed. Fig. 116 is an elevation and half plan of the tube showing the helical plate; this plate is at all points at right angles to the centre of the tube. The line or edge of plate engaging with the tube has a pitch of 6 ins., that is, the trace of the line in one complete revolution of the tube, the pitch of the outer edge of plate being the same.

To mark in the helix on the tube, divide the semi-circle ABC into six equal parts, using its radius for the purpose; divide a space of 6 ins. on the centre line as bb into twelve equal parts, and through them draw lines at right angles to bb , project the points on the semi-circle to their corresponding lines in the elevation as 1 to $1'1'$, 2 to $2'2'$, and 3 to $3'$; through these points draw the helix. The curve for the outer helix is obtained in the same manner from the points 3, 4, 5, and D on the outer semi-circle, giving the points $3'$, $4'$, $5'$, d on the lines in the elevation. The

development of the line on the tube is a very simple matter. The developed figure shows half helices by which it will be seen the

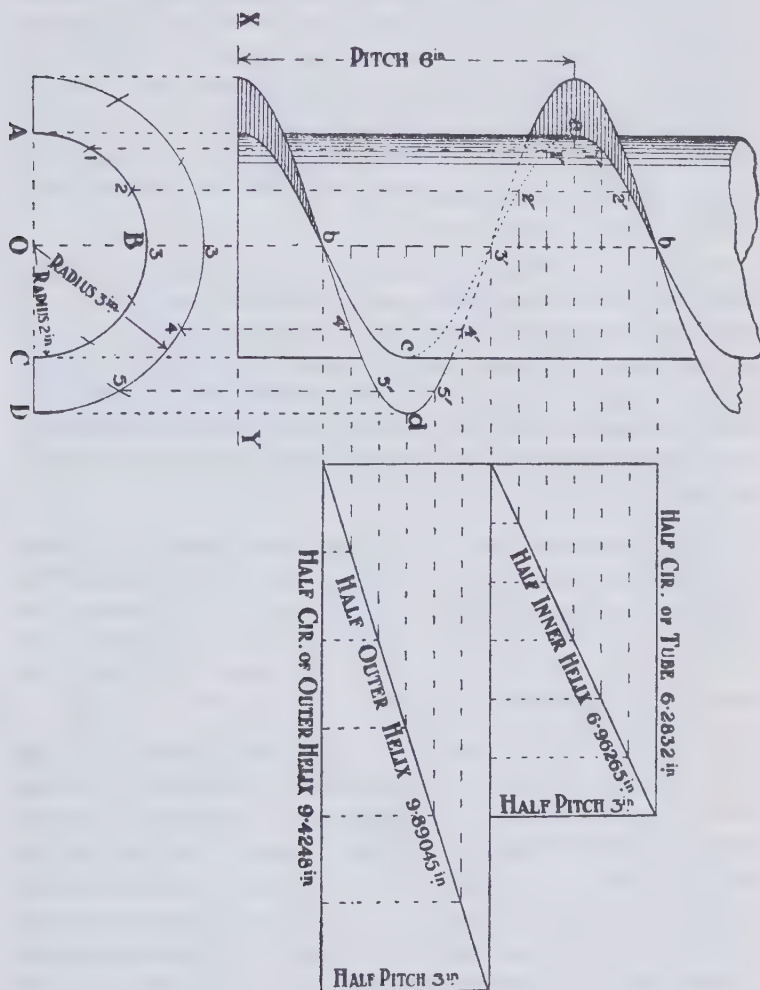


Fig. 116.

lines are straight, the direction being diagonally across the developed plate through a length equal to the pitch of the helix, an examination of the figure will be sufficient to make this clear.

The more important part of this problem is the laying out of the helical plate, and we are not sure that it can be set out by purely geometrical methods, but there is one way which will produce perfect accuracy, and that is by calculation, the process being to find incorrect radii producing an incorrect width of plate, then as the incorrect width of plate is to the correct width, so will the incorrect radii be to the correct radii.

Let the diameter of the tube be 4in., width of plate 1in., pitch of helix 6in. Find the length of the helices by the 47th proposition of Euclid as follows:—

For the tube; find its circumference:— 12.5664 , this squared and added to 6 squared will equal 193.91440896 (discard the last four places of decimals 0896), then extract the square root of 193.9144 which is 13.9253 , and will be the length of the helix on the tube. Multiply 13.9253 by $.31831$ to obtain the diameter of a circle which is to be used in finding the final correct diameter for the inside edge of the plate; the diameter produced by $13.9253 \times .31831$ is 4.4325 .

By the same process deal with the outer helix, the circumference of the plan being 6×3.1416 , which equals 18.8496 , then 18.8496 squared equals 355.2854 , to which add the square of the pitch, making 391.2854 , and from this extract the square root 19.7809 which will be the length of the outer helix, then this multiplied by $.31831$ will give 6.2962 as the incorrect diameter.

If 4.4325 be subtracted from 6.2962 the difference will be 1.8637 , but we require a difference of 2 which is the difference between the inner and outer diameters of the finished helical plate; the next part of the problem is to set out a proportion sum as follows:—

As 1.8637 is to 2 so 4.4325 is to $X = 4.75$ inches, or as the incorrect width of plate is to the correct width, so the incorrect diameter is to the correct diameter.

And as 1.8637 is to 2 so 6.2962 is to $X = 6.75$ inches.

The radius of the inner edge of the plate will, therefore, be 2.375 inches, and the radius for the outer edge will be 3.375 inches,

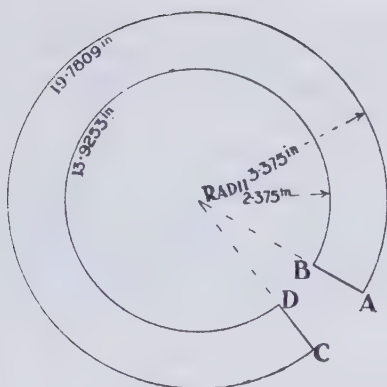


Fig. 117.

which will give a width of plate equal to 1 inch. Describe the circles as shown in fig. 117, and from any point A on the larger circle draw a line to the centre cutting the inner circle at B; from A measure off along the circle the length of plate already calculated:—19.7809, which will be from A to C, from C draw a line to the centre cutting the inner circle at D, then if the inner circle be measured the plate length will be found to be 13.9253 inches, and the plate will be correct for one complete revolution of the helix, but no doubt such a job would be made up of shorter plate lengths in order to save material, that being so it will be necessary to divide the plate into the number required per revolution, and with that as a template, mark off the total number needed. No allowance has been made for laps or flanges. The above sizes have been given in inches so that the reader may test the problem on his own drawing board, but the method applies with any sizes.

Though the above is correct for the flat shape and size of the plate, there is the question setting to shape to be considered, for such plates cannot be rolled, they must be set in a suitable block, and this may be cast in the form shown in fig. 118, having sufficient width of helical ledge to have dog holes, or a pair of blocks may be made between which the plate may be pressed, but whatever design the block may be the fact remains that the plates cannot be rolled any more than can a plate to fit the driving side of a true screw propeller blade.

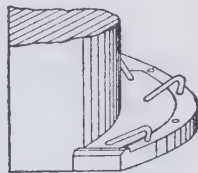


Fig. 118.

When such figures have to be made up of separate plates, they are usually connected at the angles by means of angle bars, but sometimes they are flanged, and in either case it is necessary to have the correct bevel, to find this, join $d'f'$ intersecting $e'h'$ in m ; $h'mf'$ will be a right angle. From f and d with radius mf' cut eh in m' ; join $m'd$ and $m'f$ then $fm'd$ will be the bevel for the corners. Though $d'f'$ are here joined, any line may be drawn at right angles to $h'e'$, and where the line cuts $e'd'$ and $e'f'$ must be set off from e on ed and ef , and the radius taken from the line $e'h'$ to obtain a point on eh as before.

PROBLEM 73.

To develop a figure having an oblong base, and a square top, the edges of the top and base to be parallel.

Let ABCD, fig. 120, represent the elevation of the figure on the line XY, the plan being below XY, showing the top centrally above the base, and one side bisected by the line jk . From any

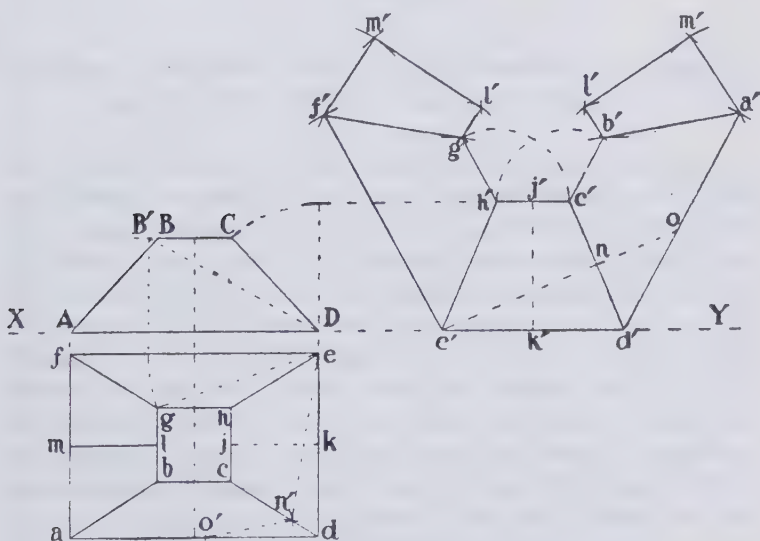


Fig. 120.

point k' on a straight line set off d' and e' equal to ke ; draw $k'j'$ at right angles to $d'e'$ and equal in length to DC , DC being the true length of kj . Through j' draw $c'h'$ parallel to $d'e'$, and on each side of j' set off c' and h' equal to jc ; join $e'h'$ and $d'c'$. One side $cdek$ has now been set out, but the adjacent side being of a different shape, the true length of a diagonal must be found by which to set out the development of that side. Join eg or db , and set off its true length in the elevation (fig. 81, third instance) in BD' . From c' and d' with radius DB' describe arcs at a' and b' , from c' with radius $c'h'$ cut the arc in b' , and from d' with radius da cut the arc in a' , join $c'b'$, $b'a'$, and $a'd'$ to complete the side, the other sides may be set out in a similar manner. To find the bevel at the corners, from e' draw a line at right angles to $c'd'$ cutting it in n , and meeting $d'a'$ in o ; set off on da , do' equal to $d'o$, and from e with radius $e'n$ cut cd in n' , join $n'o'$, then $en'o'$ will be the required bevel. In finding such a bevel the line $e'o$ must always be at right angles to the corner line which it crosses.

PROBLEM 74.

To develop a wheelbarrow body, the centre section being given, the top to be rectangular, and the sides to be flat.

Let $ABCD$ represent the centre section on the line XY . Produce AB and DC till they meet in G . Draw ad parallel to XY , and to it project the points A, B, C, D, G , in a, b, c, d , and g . Set off ae and df equal to half the width of the top; join ef , eg and fg . From b and c draw lines parallel to ae and df meeting eg in h and fg in j ; join hj and produce the line in kl . The half size of the bottom will now be set out in $bhjc$. Draw a line $a''d''$ parallel to ad , and to it project the points b and c in $b'c'$, set off on each side of $b'c'$ the points $h'j'$ equal to h and j from bc , and join them to complete the full shape of the bottom. From B set off Ba' on XY equal to BA , and project a' to a'' , make $a''e'$ equal to ae , join $e'h'$; from C set off Cd' equal to CD , and project d' to d'' , then set off $d''f'$ equal to df , join $f'j'$. Produce $h'j'$ in $k'l'$, and

from h' with radius $h'e'$ describe an arc, from j' with $j'f'$ radius describe an arc. Project e at right angles to kl in m , and project m to $k'l'$ at right angles to XY in m' ; at m' draw a line at right angles to $k'l'$ till it meets the arc in e'' , join $e''h'$. From e'' with

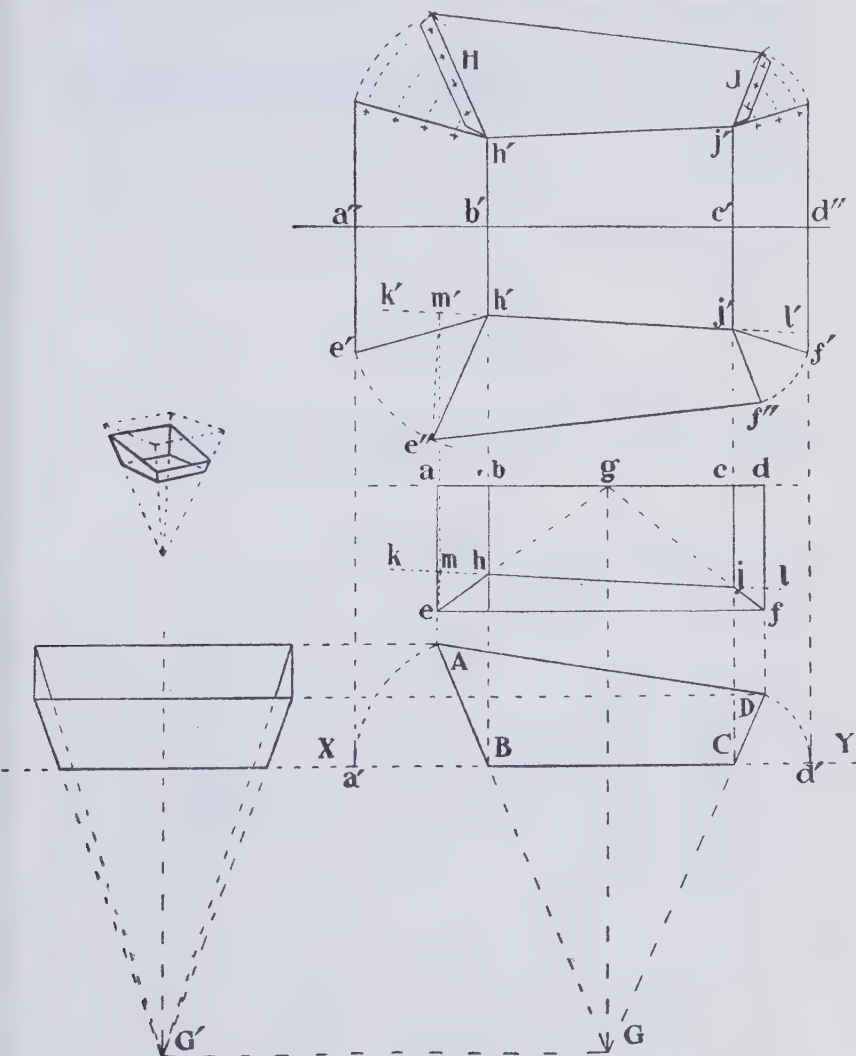


Fig. 121.

radius AD cut the arc described from j' in f'' , join $f''j''$, and $e''f''$. The portion above $a''d''$ will be set out from the portion below. The flange at H and J may be added and the holes marked in, after which arcs may be described as shown to obtain the position of the holes on the other part.

The front view with the sides meeting at G' shows how the figure is a part of a tapering solid, as may be seen in the miniature, and though the four sides meet in one point in this case it is not

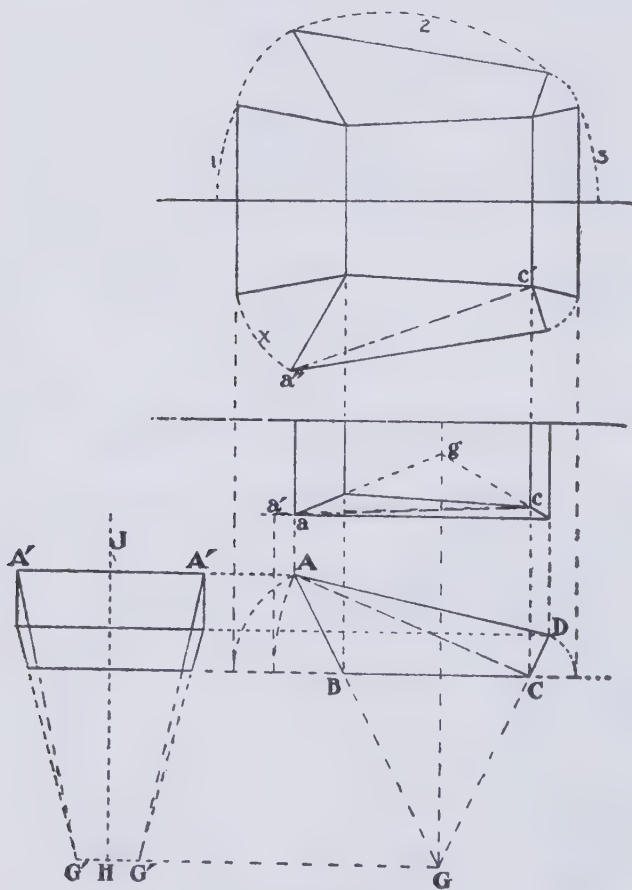


Fig. 122.

essential that they should, they may take the form of a wedge if produced, as in fig. 122, ABCD is not only the centre section, but is also an elevation of the side, the lines AB, and DC produced, meeting, at G, but the front elevation shows the corners produced meeting at G'G', and forming equal angles with JH, while G'G' is parallel to A'A'. The development may be set out in the same manner as with fig. 121, but a slight difference is made in this figure to show another method of finding the shape of the sides. After laying out the bottom and ends, find the true length of CA in ca' , and form c' as centre with radius ca' cut the arc x in a'' and complete the development as before explained. Any curvature desired for the top may be added after developing, as shown at 1, 2, and 3.

PROBLEM 75.

To develop a figure having a square base and circular top parallel to each other, the centre of the top to be over the centre of the base.

Fig. 123 represents the plan, elevation, and development of the figure, the plan of the base being ABCD, and the plan of the top being EFGH. The elevation is AefgB. Divide the circle into four equal parts by lines parallel to the base lines AB, &c., producing the points EFG and H, join BF, and BG. Divide the arc FG into any number of equal parts, in this instance four, and from the points obtained draw lines to B, as 1B, 2B, 3B, the length of B1 will be the same as B3. From B with radius BF describe an arc cutting AB in F', project F' to eg in f' , join $f'B$ which will be the true length of FB; treat B3 and B2 similarly to find their true lengths in B1' and 3', B2'. Produce EG through J to g' , and set off Jg', equal to Bg; join Bg', then BJg' will be the true shape of BJG. From B with radius B1' make an arc at 1'', and again from B with radius B2' make an arc at 2'' and in a similar manner from B with radius B3' make an arc at 3'', the arc at f'' being made with radius Bf' or Bg'. From g' with radius G1 step off from arc to arc the points 1'', 2'', 3'', f'' , through

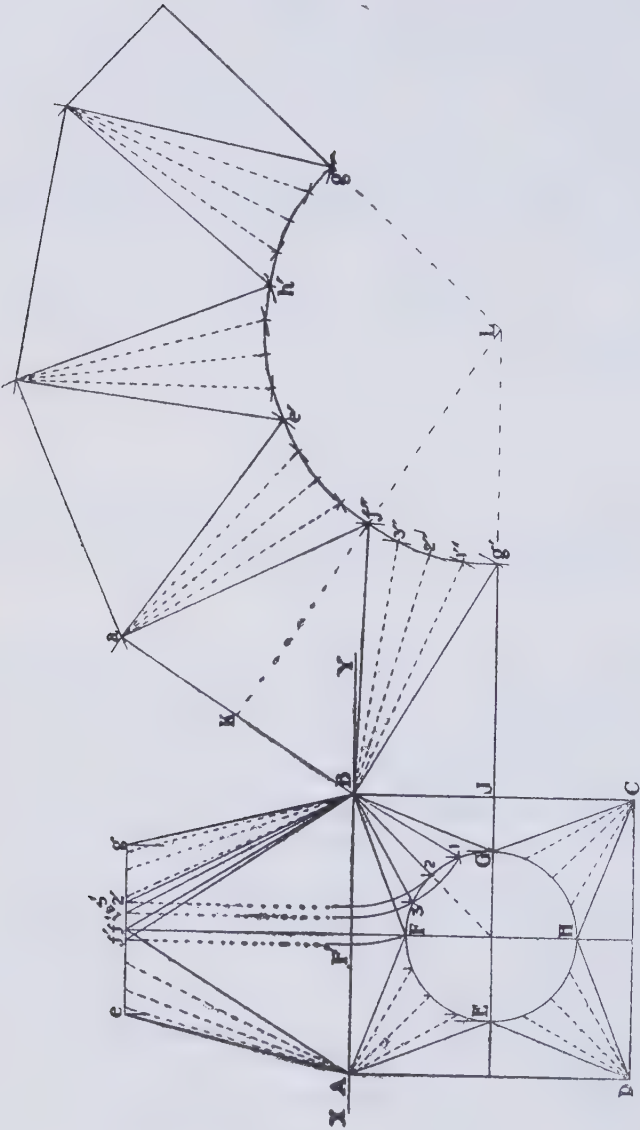


Fig. 123.

which draw a fair curve. From B with BA radius make an arc at a , and from f'' with radius $f''B$ cut the arc in a ; join Ba and af'' . The remainder of the figure may be developed in the same manner.

A very near solution for the developed curve may be obtained by finding the point f'' as before explained, and then bisecting Ba in K, and from K draw a line through f'' meeting Jg' produced in L, then from L as centre and radius Lg' describe an arc $g'g''$ which will be found to be so slightly different to the curve already set out that one might almost be excused if it were done in this way instead of by the more detailed process.

PROBLEM 76.

To develop a figure having a square base and circular top parallel to each other, and one point of the circle to be perpendicularly above the centre of one side of the base.

Fig. 124 represents the plan, elevation, and development of the figure, the plan of the base being ABCD, and the plan of the top being EFGH, the point G is perpendicularly over the centre of the side BC; the elevation is AegB. In general treatment this figure is very like the previous problem, the difference being that instead of developing from one quarter of the plan, it is necessary to deal with a half plan. Divide the circle into four equal parts by lines drawn parallel to the base lines AB, &c., then divide the semi-circle EFG into four equal parts as by K and J (in the case of large figures of this description the semi-circle should be divided into as many equal parts as may be conveniently dealt with), join AE, AK, AF, BF, BJ, and by fig. 81 set off their true lengths in Ae' , Ak , Af' , Bf , Bj . Produce EG to G' equal in length to Bg as shown by the arc gg' projected at right angles to XY from g' to G'; join BG' which is the true length of BG. From B with radii Bj, Bf, describe arcs at J', and F', then from G' with radius GJ cut the first arc in J', and from that point with the same radius cut the next arc in F', join

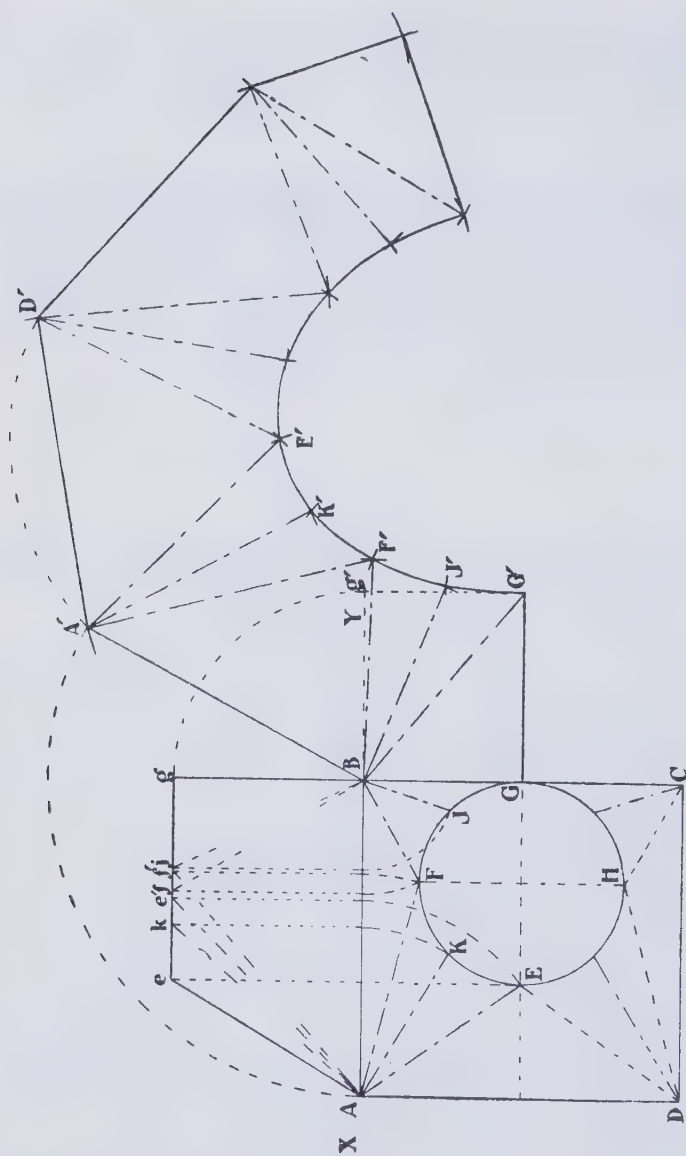


Fig. 124.

these points to B. From F' with radius Af' describe an arc at A' , and from B with radius BA cut the arc in A' , join BA' , $A'F'$. From A' with radii Ak , and Ae' describe arcs at K' and E' , and from F' step off K' and E' equal to $G'J'$. From A' with radius $A'B$ make an arc at D' , and from E' with radius $E'A'$ cut the arc at D' , join $A'D'$, $D'E'$. Continue the process for the remainder of the development, and through the points $G'J'$, &c., draw a fair curve for the top edge of the figure.

The parts to be bent will be those at $BG'F'$, $A'F'E'$, the large triangles as $A'E'D'$ remaining flat.

PROBLEM 77.

To lay out a bonnet for a forge.

Let ABCD, fig. 125, represent the elevation of the bonnet, and $aE3dc$ the half plan of the base, the top being a circle of which $b3c$ is the half plan. The radius of the corner E3 is the same as the top. Divide the semi-circle $b3c$ into six equal parts, as 1, 2, 3, 4, and 5; join the points 3, 4, and 5 to d . Join Eb , and draw 11, 22, and 33 parallel to Eb . From b with radius bE describe an arc EE' meeting ba produced; project E' to XY in E'' , and from B with radius BE'' describe an arc $E''E'''$, then draw a line from A at right angles to AB till it meets the arc in E''' ; join $E'''B$. ABE''' will be the true shape of abE . From D with radius DC describe an arc meeting XY in C' ; project C' to C'' till it meets bc produced in C'' , join $C''d$, then cdC'' will be the shape of half the triangle at the back of the bonnet. Draw a line xy parallel to Eb , and to it project the points a , E, 1, 2, and 3, on the base. Draw the line Z parallel to xy and distant from it equal to DC; project to Z the points b , 1, 2, and 3 on the semi-circle, join $1'$ on xy to $1'$ on Z, then $1'1'$ will be the true length of 11. Project the point a' to $1'1'$ at right angles to it in a'' , and from each of the other points on xy and Z draw a line at right angles to $1'1'$. From a'' with radius AE''' cut the line projected from e in e' , and from a'' with radius AB cut the line projected from

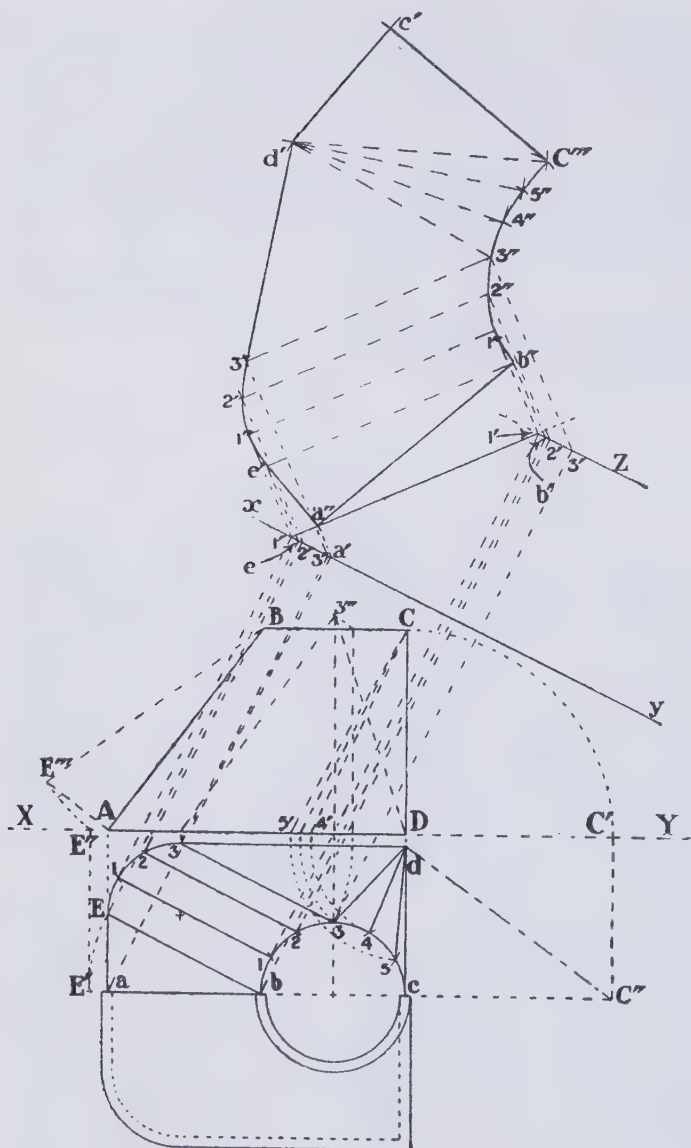


Fig. 125.

b' in b'' , join $e'b''$ which should then be parallel to $1'1'$. Now apply a thin lath to the plan, and set one end fair to the point a , and bend it to the curve E , 1, 2, 3, and mark these points on the lath. Apply the lath to the development setting the end fair to a'' , and bend it so that it will engage fairly with e' and the other lines projected from $1'$, $2'$, $3'$ when the points $1''$, $2''$, $3''$, may be marked from the lath. From $1''$, $2''$, $3''$, draw lines parallel to $e'b''$ till they meet their corresponding lines projected from $1'$, $2'$, $3'$, on Z in $1''$, $2''$, $3''$. From $3''$ on the base with radius $3d$ make an arc at d' , and from $3''$ on the inner curve with radius $D3''$, the true length of $d3$, cut the arc in d' ; join $d'3''$, $d'3''$. Set off the true lengths of $d4$ and $d5$ in $C4'$ and $C5'$ (fig. 81), and from d' with radii $C4'$, $C5'$, dC'' , describe arcs at $4''$, $5''$, and C'' , then from $3''$ with radius $c5$ on the semi-circle step off the points $4''$, $5''$, C'' , and draw a fair curve from b'' to C'' , passing through $1''$, $2''$, $3''$, $4''$, $5''$. From C'' with radius $C''c$ make an arc at c' , and from d' with radius dc cut the arc in c' ; join $d'c'$, and $c'C''$ to complete one half of the development from a to c in the plan. Any moulding required at the bottom must be bent on edge to the outer edge of the development before being bent to the shape in the plan.

PROBLEM 78.

To develop an oblique or scalene cone.

Fig. 126 is the elevation and half plan of the scalene cone, and is the shape of the fire-box fitted to a certain type of multi-tubular donkey, or upright, boiler. In marking out the plate for such a figure one might be tempted to proceed by treating it as the frustum of a right cone with the apex at E and the top and bottom cut at an angle to the centre-line; and while the resulting development will be of a shape somewhat similar to that in the figure, it will not be correct, for the top and bottom in such a case would be developed from ellipses, whereas they have to be circles, and in setting out the joggle for the water

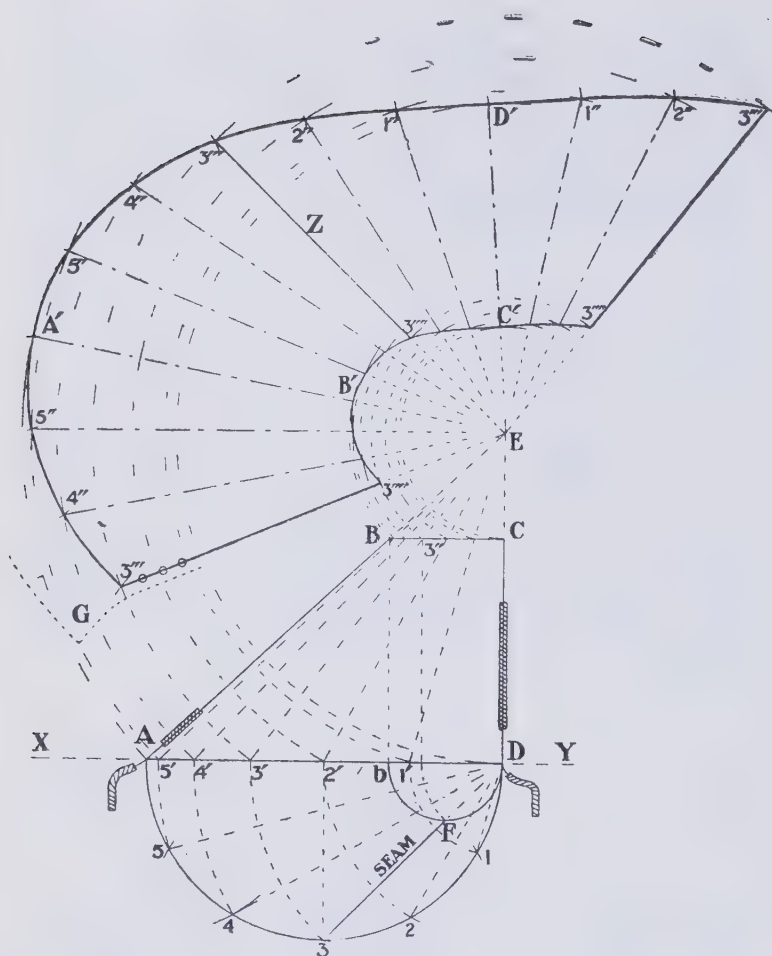


Fig. 126.

space at the bottom there would have to be considerably more set-out at the sides than at the front and back.

Let ABCD represent the elevation on the line XY, the base AD being taken as a circle just above the joggle, and BC to be a circle parallel with the base. Produce AB and DC till they meet at E, then E will be the apex of the figure in which all

straight lines on the surface meet. On AD describe the semi-circles A3D, and bFD. Divide A3D into any number of equal parts, as 1, 2, 3, 4, 5. From D, which is the plan of E, with radii D1, D2, D3, D4 and D5 draw arcs meeting AD as in 3', and from the points on AD draw lines towards E till they cut BC as at 3" drawn from 3', then each of these lines will be the true length of its corresponding line drawn from the points on the semi-circle A3D towards D till they meet the semi-circle bFD, as 3'3" is the true length of 3F.

To set out the development, from E with radii EA, E5', E4', &c., on AD describe a series of arcs as shown in the figure, and as the seam is usually on the line 3F let the development commence on the arc drawn from 3', then from 3'' with radius A5 step out from arc to arc the points 4'', 5'', A', 5'', 4'', 3'', 2'', 1'', D', 1'', 2'', 3'', from these points draw lines to E, and through them also draw the fair curve which will be the development of the base. From E with radii EB, &c., on BC cut the respective straight lines in the development as shown in 3''' from 3'', and through the points obtained draw a fair curve which will be the development of the top. The line Z is drawn through the figure at the part representing 3F in the plan, and that line may be taken as dividing the development into two parts, one for the front plate and the other for the back plate. The extra for the joggle at the bottom will require to be added as shown at G, and after the seam lap has been lined in extra should be added as shown because there will be considerable draw away when joggling the plates. The straight lines on the development are rolling lines.

PROBLEM 79.

To develop a scalene cone fire-box plate showing the hole for the fire-hole tube.

Before dealing with this problem, the reader is advised to read up Problem 78, this one being very similar in regard to the

laying out of the plate, the principal difference is a slope in the back of the fire-box in this problem, whereas in the previous one the back is assumed to be vertical, or parallel to the boiler shell. The top and bottom are taken as parallel and circular, and the fire-hole tube is to be elliptical in right angle section; the figure is of course greatly exaggerated in regard to the tube for the purpose of explanation though the principle for marking the hole in the plate remains the same.

Set out a side view of the fire-box in ABCD, fig. 127, the line AD being taken as just above the commencement of the joggle; it will be noticed the lines are as at the centre of the thickness. Produce AB and CD till they meet at E. E is the apex of the figure in which all straight lines on the surface meet. Draw FG representing the boiler shell plate, and at the proper position mark off the fire-hole tube as shown in heavy section. On FG set out a half ellipse representing the tube, and divide it into any number of equal parts, it is here divided into six, and the ellipse is taken as the inside size, but the outside could be taken; it only means a little more allowance in this case in respect to the extra size of the hole to allow for the turn of the flange of the tube in order that there shall be no curl of the plate edge when fitting up, this may be seen in the section shown in the figure. Bisect AD in H, and from H draw a line towards E till it meets BC in J. Project all the points on the ellipse to HJ in F', 1', 2', 3' 4' 5' and G', these lines will intersect AB in G'', &c., to F'', and the points on HJ will be centres of parallel circular sections which intersect parallel sections of the tube in points on the line of interpenetration. In the workshops the line DA produced would be made to serve the purpose of the line XY, but to avoid confusion with the sectional view the line XY is here drawn below and parallel to AD. Project H and J to XY in *h* and *j*, then from *h* as centre with radius HA describe the semi-circle *ad*, and from *j* as centre with radius JB describe the semi-circle *bc*. Project E to XY in *e*, then *e* will be the plan of the apex. Divide the semi-circle *ad* into any number of equal parts, say six, and join the points obtained to *e*, as *8e* intersecting the semi-circle *bc* in 8'. From *e* as centre and radius *e8* draw an arc to XY, and from

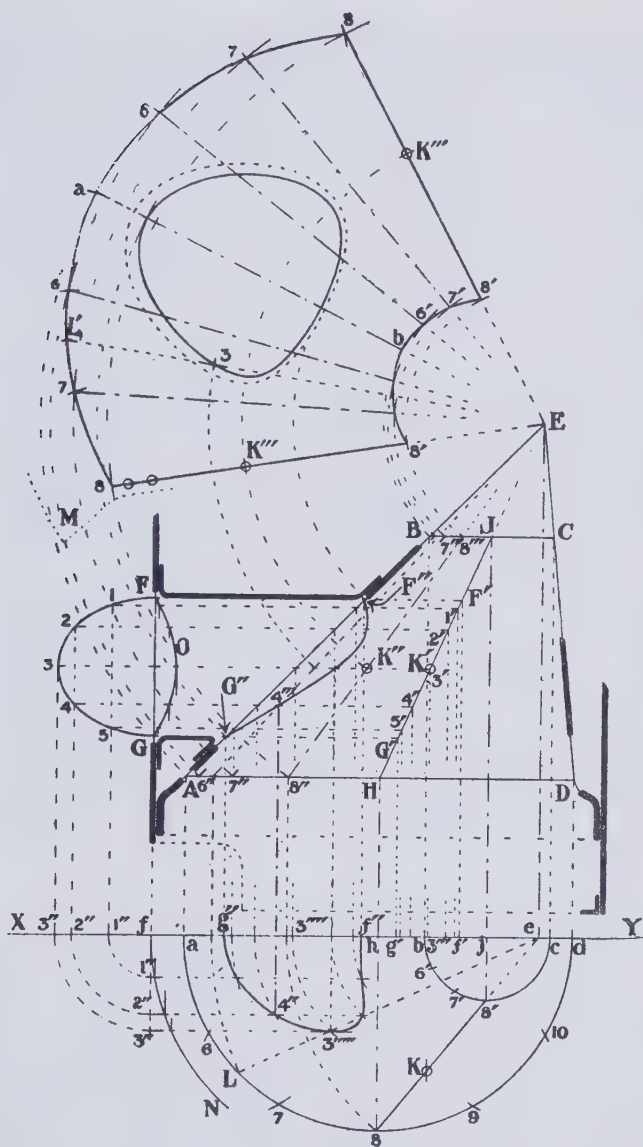


Fig. 127.

there project the point to AD in 8", draw a line from 8" towards E till it meets BC in 8'', then 8"8'' will be the true length of 88'. The points 6, 7, 9, and 10 are to be treated in the same manner if it is desired to develop the whole cone, but as it is here intended only to lay out the front plate, the seam is taken as on the line 88' and the points 6 and 7 only have been projected to AD, the projectors not being shown to avoid confusion of lines. From the points 6"7"8" draw lines towards E till they meet BC, then by following the instructions in Problem 78 the development of the plate may be set out from E as centre.

To show the shape of the hole in the plate for the fire-hole tube, project the points on the ellipse to XY in *f*, 1", 2" 3", and from *f* as centre continue the projection by arcs meeting G*f* produced, then again from these points draw lines parallel to XY, as 3"3'''. Project the points F'1'2'3'4'5' and G' to XY as at *g'f'*, and project the points G" to F" on AB to XY in *g"* to *f"*, then from the points between *g'f'* as centres in succession with radius to the points between *g"f"* in succession describe a series of arcs cutting the lines drawn parallel to XY from 1", 2", and 3" as with the point 3''' produced by describing an arc with 3''' as centre and radius 3''', the arc meeting the line drawn from 3" in a point 3''' on the interpenetration line. Through the points draw a fair curve from *g"* to *f"*. Project the points on the curve *g"f"* to the elevation till they meet their corresponding lines drawn from the ellipse as with 4" 4'', through the points thus obtained draw a fair curve from F" to G" which will be the elevation of the interpenetration line on the cone. To set out the shape of the hole in the developed plate, the points are to be found in the manner explained for the point K. Let it be assumed the point K in the plan is to be shown in the development, from *e* draw a line *e*8 passing through K, then from *e* with radius *e*8 describe an arc meeting XY, and from that point again project to AD in 8", from 8" draw a line towards E meeting BC in 8'', and to this line draw a line from K', the elevation of K, parallel to AD meeting 8"8'' in K"; it may be mentioned that 3' and K' is the same point except that 3' represents a point on the centre line of the cone, whereas K' represents a point on the surface. The line

8"8'" is the true length of 88', and the point K" is the true distance of K' from E. From E as centre and radius EK" describe an arc meeting the lines 88' on the development in K'"K'", in a similar manner any number of points on the interpenetration line F"G" may be set out through which to draw the fair curve for the development of the fire-hole, this may be followed by tracing the point 3'" on the line eL till its position is found on EL' in the development at point 3. The section in heavy lines will show the difference which has to be allowed for the enlargement of the hole on account of the necessity of avoiding any curl to the edge of the fire-box plate on to the turn of the flange of the tube, this is shown in the development by the dotted line, there being more allowed at the bottom than at the top on account of the angle of the tube to the fire-box. The amount for the bottom joggle is to be added as shown at M, extra being added on to the seam line to allow for the draw away when joggling, the exact amount needed depends on the depth of joggle or waterspace.

The arc N represents the boiler shell plate, and to it have been projected the points 1", 2", 3", and from these points lines have been drawn to their corresponding lines in the elevation through which the curve O has been drawn, and by applying Problem 45 the hole in the boiler shell may be set out, due allowance being made for the enlargement of the hole for the turn of the flange of the tube.

PROBLEM 80.

To develop an elliptical fire-hole tube.

Let ABCD, fig. 128, represent the fire-hole tube showing the flanges as in the previous figure. Produce the centre line 33, and above the tube set out a half ellipse E to the size at the centre of the thickness, and divide it into any number of equal parts, say, six, and from the points obtained draw lines through the figure parallel to 33. Draw any line FG at right angles to 33. To set out the development draw any line F'F' equal in length to the

circumference of the full ellipse, and divide it into twelve equal parts; at each end draw a line $B'C'$ at right angles to $F'F'$ and through each point on $F'F'$ draw a line parallel to $B'C'$, then from $F'F'$ set off the lengths of lines corresponding to those on

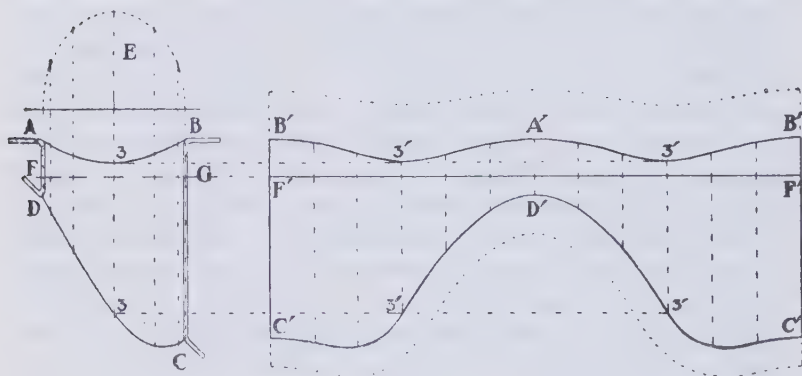


Fig. 128.

the tube above and below FG as with $3'3'$, and through the points obtained draw fair curves which will give the flanging lines. The figure shows the development set out with the weld to be on the line BC , this being the line where the flange is strained the least, but of course the development may be set out with any desired position for the weld as at AD for instance, when the edge of the plate would be taken as from the line AD in $A'D'$.

In adding the amount for the flange, care must be taken that there is extra allowed where the stretching is severe, especially at D , and as the flanging is being done the edge should be jumped in order to keep the thickness, otherwise the plate will work out to a very thin edge, and any attempt to jump it then will not only tend to alter the set of the flange, but will simply raise a ridge at the edge instead of thickening the plate behind. The shell flange is mostly double rivetted, the width being about 4 inches, and as the tube is small for such a width, one is apt to misjudge the amount to add for flanging, but a little calcu-

lation will remove this uncertainty and ensure having sufficient material while not having such an excess that renders the work harder than is necessary. To find this, the area of the finished flange in square inches must be converted into length of tube, and a small amount, say a quarter of an inch, added for waste and trimming up; thus if the tube is 10in. \times 14in. and the width of flange measured inside is 4in. the area of the ellipse 10in. \times 14in. taken from the area of an ellipse 18in. \times 22in., which is the tube size plus the flange, will be the area of the flange in square inches, then if this be divided by the circumference of the tube the result will be the net amount of flange required. To find the area of an ellipse, add together the major and minor axes, divide by two, square the result, and multiply by .7854, thus the area of 10in. \times 14in. will be 113 square inches, and the area of 18in. \times 22in. will be 314 square inches, the fractions being discarded, the difference between these areas will be 201 square inches, which divided by the circumferences of the tube equal $5\frac{3}{4}$ inches as the amount to be added for flanging with, say $\frac{1}{4}$ of an inch extra for waste and trimming up. When flanging, it will be found best to let the blows fall so that the root of the bend is established at once, as shown at A, fig. 129, if it be done in the manner shown at B there will be a thinner edge to the finished flange, and in working up the root of the bend there will be a great tendency to produce too square a corner.



Fig. 129.

PROBLEM 81.

To lay out the template for a dome.

The method of developing a dome plate is based on the convex area of the segment of a sphere being equal to a circle with radius equal to the chord of half the segment. In fig. 130 the segment ABC of the sphere D has a certain convex area, and if a circle be described with BA radius it will be found to

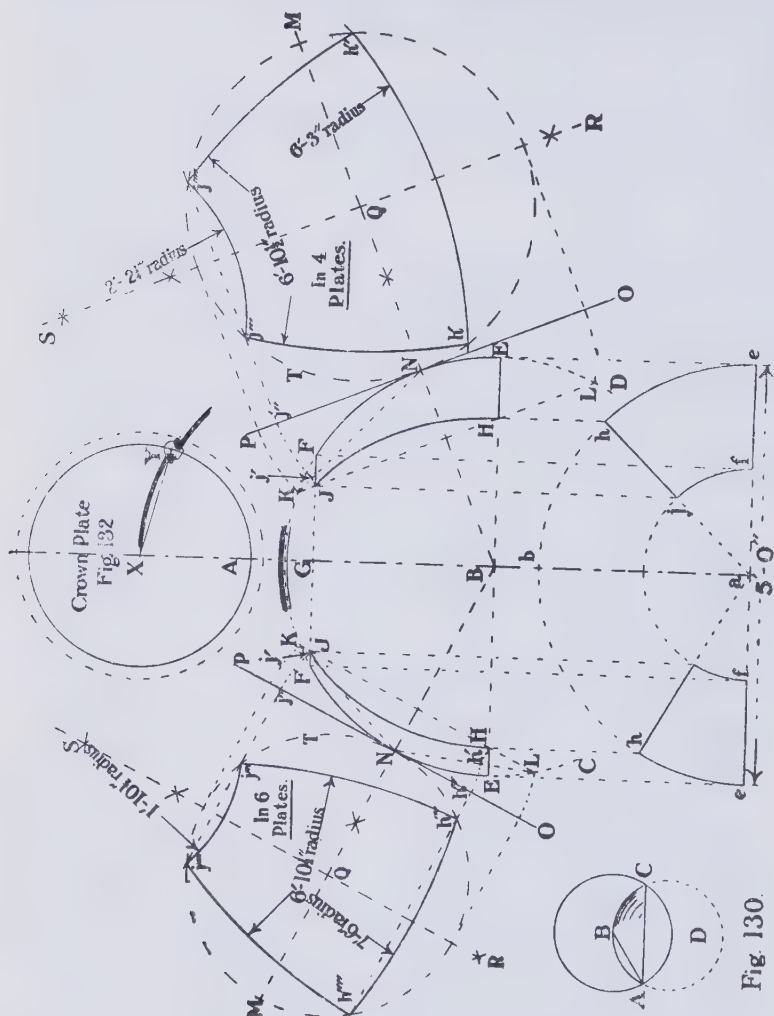
equal the area of ABC, if then a plate be cut with BA as radius, and it be dished to the shape of ABC it will be found to have contracted around the edge, and to have stretched over a certain area about the centre, the result being that while the shape of the plate has changed the area has not altered. From this the theory was deduced in our earlier work that "by finding where the four points of the plate would touch the surface of the hemisphere, and by completing the segment of which the plate is a part we find the extremes within which the plate must lie, and having found the circle which shall equal the segment we proceed to take from that circle those parts which are not required, and what remains must be the required plate." While the theory is quite correct as applied to a complete circle in the sense that if a plate be marked off on the circle which is equal to the full segment, and then the full circle dished, the parts not required could be removed, leaving the plate in perfect form, it does not produce quite such satisfactory results when the plate is cut to the shape before dishing, this is on account of the change of position in respect to the contracting and stretching, and though in the case of a dome which has to be plated in six side plates, with the diameter of the crown equal to the radius of the hemisphere the results would be quite all right, it is by reason of the centre of the plate being so near the centre of the segment of which it is a part. Having given this matter very careful consideration, and carried out some experimental tests with six plates and four plates to the dome, the diameter of the crown in both tests being equal to the radius of the dome, we have decided on a slight alteration in the application of the theory, and instead of developing the figure entirely we have ascertained radii for the setting out of the edge curves which will be of advantage, though it is as well to state that true arcs for the edges do not produce exact results on account of the unequal contraction and stretching which takes place in the process of setting to shape, the edges tending to buckle severely near the corners and instead of the plate thickening at those parts, it extends, giving the plate edge a slight fulness. The radii given here is the result of experiment, and except for the fulness just

referred to, the results on a six plate dome, and on a four plate dome were all that could be desired. We have not had an opportunity to make tests on other numbers of plates in the dome, but hope to do so at some future time.

Let it be required to make a dome of six plates and the crown, the diameter of the crown to be equal to the radius of the dome (the left of fig. 131).

Draw a line Aa of indefinite length, and from any convenient points a and B on Aa with radius equal to that of the dome at the centre of its thickness describe the arcs KC and be . Draw BE and ae at right angles to Aa , and from E and b with radius EB cut the arcs in F and h . Draw FG at right angles to Aa and join ha . Project F to ea parallel to Aa in f , and from a with radius af describe an arc meeting ha in j . Project j to FG in J , and h to EB in H . The curve HJ need not be drawn. Through H and J draw a line meeting the arc in K and L . Bisect KL by the line MB intersecting the arc in N . Through N draw a line OP parallel to KL , and through any convenient point Q on MN draw the line RS parallel to OP . RS will be the centre line of the template. Join NL and NK , these will be equal to each other, then from Q with radius NL describe the circle T . Project the point H to NL at right angles to KL in h' , and from N with radius Nh' draw an arc $h'h''$, then from h'' draw a line parallel to MN till it cuts the circle T in $h''h'''$ which will be the bottom corners of the template. In the same way project the point J to NK at right angles to KL in j' , and from N with Nj' radius draw an arc $j'j''$, and from j'' draw a line parallel to MN till it meets the circle T in $j''j'''$ which will be the top corners of the template. If the dome be taken as 5ft. diameter at the centre of its thickness, set the trammel to 1ft. 10½in., and from $j''j'''$ draw arcs intersecting at S , and from S with the same radius draw the arc $j''j'''$ for the top. Set the trammel to 7ft. 6in., and from $h''h'''$ draw arcs beyond S from which to describe the arc $h''h'''$, the radius for the sides being 6ft. 10½in. The arcs being drawn the template will represent butt edges, but as it is usual to lap such plates

let the edge nearest M represent the inside lap, then that edge will need to be shortened $\frac{1}{4}$ th the thickness at each end whilst



Figs. 130, 131, and 132.

the opposite side will need to be lengthened at each end a like amount, the top and bottom curves being adjusted accordingly.

If the plates are to be punched the template had better represent the outside, that is to say all plates marked from it will be dished with the marks on the outside as that will mean reversing one seam only. If convenient make the template of sheet iron, taking care to pitch off the holes for the side seams very exact. The plates may now be marked from the template, and all holes centred with a good centre-punch mark, the plates' edges sheared from their proper side, the outside corners thinned, and they will then be ready for dishing, after which the holes may be drilled or punched to the centre marks, but if desired the outside lap may have only its centre hole put in when the whole dome may be assembled and the outside laps marked off from the inside laps which will ensure perfect work, and avoid any reamering due to the buckling previously referred to.

In domes of different diameter to that given the various radii will be in proportion, thus if the dome were to be 6ft. diameter each of the radii would be increased $\frac{1}{4}$ th, which would give the top radius as 2ft. 3ins., the bottom radius 9ft., and the side radius 8ft. 3in., the four points being first found by the method given.

To set out the size for the crown plate take the direct radius from the centre of thickness at the top to the centre of the rivet hole through the centre of thickness as XY in fig. 132, and describe a circle which will be the line for the holes; add on the lap as shown by the dotted circle for the complete size.

To set out the template for a four plate dome, the diameter of the crown plate to be equal to the radius of the dome. (At the right of fig. 131).

First set out the four points for a six plate template, then by the same process find the top points $j'''j'''$ on the four plate template, and instead of finding the bottom points by that method take the direct distance $j'''h'''$ on the six plate template as a radius, and with that from j''' and j''' on the four plate template cut the circle T in h' and h'' which will give the bottom points. The

radius for the side seams will be the same as for six plates, but the radius for the top and bottom will not be the same. Taking the dome to be the same size as in the six plates just explained, the radius for the top will be 2ft. 2 $\frac{1}{4}$ in., the radius for the bottom will be 6ft. 3in. It will be noticed in comparing the two templates how near the centre of the plate is the point Q for the six plates, and how much nearer the bottom edge it is on the four plate template.

If the dome had to be 6ft. diameter the radii given would require to be increased $\frac{1}{8}$ th, and similarly in proportion for any other diameter, the two top corners being found first, and the bottom corners obtained from the six plate size. When dishing such plates care should be taken to work them so that buckling is prevented as much as possible.

TRIANGULATION.

There are many figures which cannot be developed by the usual process of geometry, and a method known as triangulation has to be resorted to in order that the difficulty may be overcome, and while by such a method a very nearly correct solution may be obtained, it is very rarely the shape of the development can be called true when the figure is such that curved lines have to be represented by straight lines.

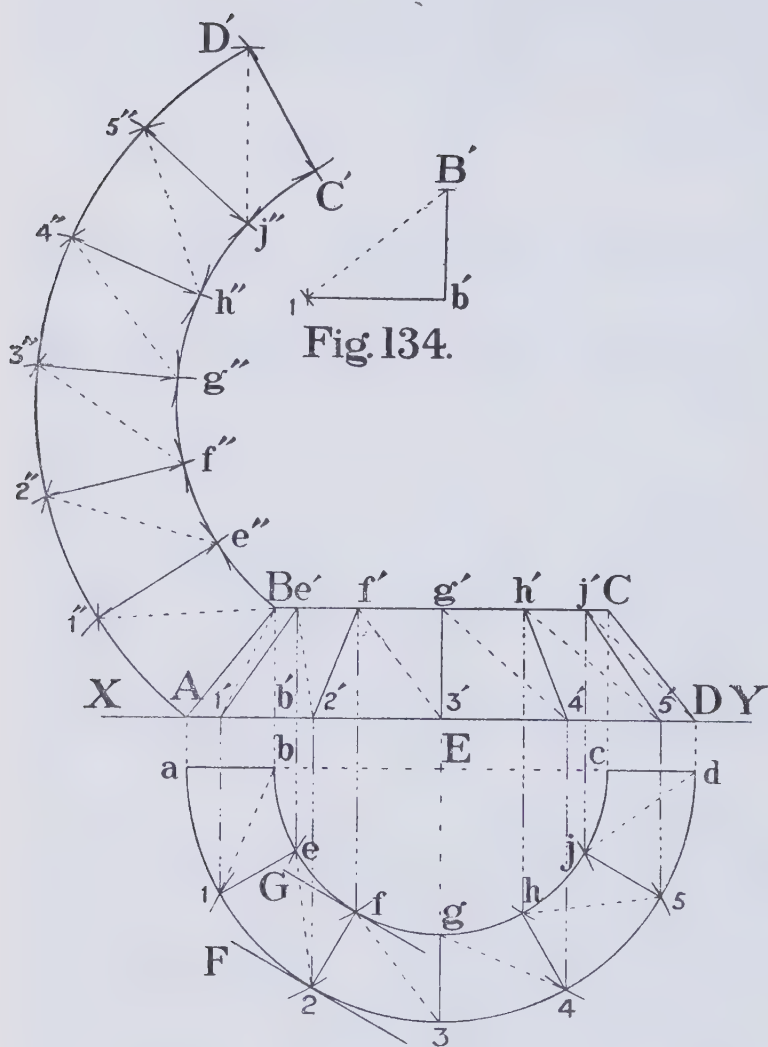
The general principle of the method is to set out on the surface of the figure a number of adjacent triangles, curved lines being regarded as straight, and each forming a side to a triangle, then by finding the true (it is not quite correct to say "true") shape of them they are set out in development till they take the required form of the developed figure. In such problems it is not always advisable to divide into equal parts, because to do so would mean having more curved lines represented by straight lines than is necessary, it will be better to divide one edge only into a number of equal parts, then by a series of tangent lines points may be found which, when connected in pairs, produce rolling lines that remain straight at all times.

When the top and bottom of a figure are parallel the tangent lines will be parallel to each other, but when the top and bottom are not parallel the tangent lines will meet on a line common to all. The next two problems are intended to illustrate these principles.

PROBLEM 82.

To develop the frustum of a right cone, the top and bottom being parallel.

Let ABCD, fig. 133, represent the elevation of the frustum on the line XY, the half plan being the semi-circles *ad* and *bc*. Divide *ad* into any number of equal parts as 1, 2, 3, 4, and 5, then at each point draw a line tangent to the arc as F tangent at the point 2, then as the top is parallel to the base, draw a line G parallel to line F and tangent to the arc *bc* giving the point *f*, join 2*f* which if produced would meet the centre E. The lines 1*e*, 3*g*, 4*h*, and 5*j* are found in the same manner. To proceed by triangulation, join 1*b*, 2*e*, 3*f*, 4*g*, 5*h*, and *dj*, then the plan is divided into a series of triangles as *abl*, 1*be*, etc. Project the points on the semi-circles to the elevation as 2 to 2', and *f* to *f'*, and join the points on AD to those on BC in a similar manner as on the plan. The lines 1*b*, 2*e*, 3*f*, 4*g*, 5*h*, and *dj* are in reality curved lines, but for the purpose of triangulation they have to be regarded as straight. It is now necessary to find the true length of the lines forming the triangles, and as all the heavy lines *ab*, 1*e*, etc., are the same length, and are represented by AB there will be no need to consider them further, AB being the true length of them all, but the lines 1*b*, 2*e*, etc., must be dealt with to ascertain their true length. As the vertical height of each line is the same, and their length in the plan is also the same, there is only one true length to find. Draw a line 1*b'*, fig. 134, equal to 1*b* in the plan, and at the point *b'* erect a perpendicular *b'B'* equal to the vertical height *b'B* in the elevation, join B'1 which is to represent the true length of 1*b*, etc., in the plan. From B with radius B'1 draw an arc at 1'', from A with radius *al* cut



Figs. 133 and 134.

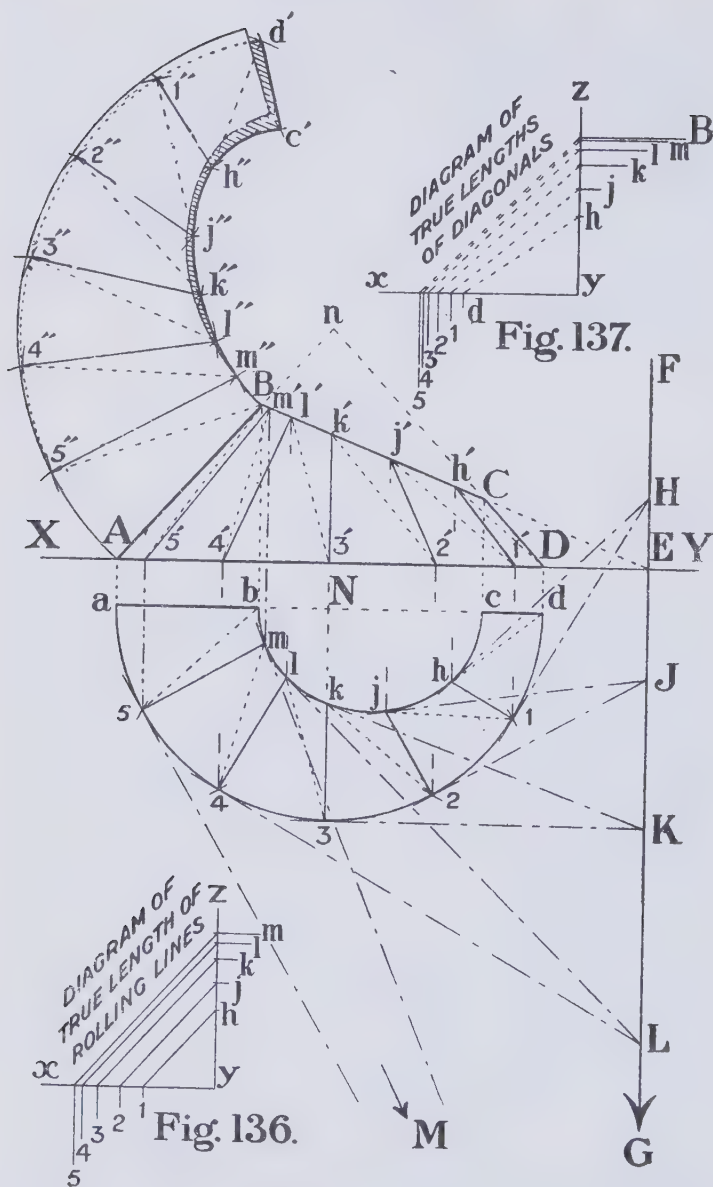
the arc at $1''$, from $1''$ with radius AB draw an arc at e'' , and from B with radius be cut the arc at e'' repeating the operations from

e'' and $1''$ to obtain the points $2'' f''$, and so on for the remainder. Through the points obtained draw fair curves to complete the development. It should be borne in mind that to obtain good results with this method it is essential to divide the figure into such a number of parts that the lines which are straight, but represent curves, shall in reality be as nearly straight as possible, and in the figure given above it would be advisable to divide the arc ad into at least twelve equal parts for the fewer the parts the greater the inaccuracy in the development, as will be shown in the next problem.

PROBLEM 83.

To develop the frustum of a right cone when the top is not parallel to the base.

Let ABCD, fig. 135, represent the elevation on the the line XY, the half plan being the semi-circle ad and the semi-ellipse bc . Produce BC till it meets AD produced at E, and through E draw a line FG at right angles to AE. Imagine now a plane lying on BC and meeting a plane lying on the ground line XY at the point E, BE will be the elevation of one plane, and AE the elevation of the other, the line FG being of indefinite length and representing the horizontal trace of the point E in the same manner as a book with the cover lifted to the angle AEB, the line FG being the side of the book, and the figure ABCD within it. Divide the arc ad into any number of equal parts as 1, 2, 3, 4, and 5, and at these points draw lines tangent to the arc till they meet the line FG in H, J, K, L, and M, then from these points on FG draw lines tangent to the curve bc and meeting it in the points h, j, k, l , and m ; join $1h, 2j$, etc., which will be straight lines on the figure and rolling lines in the development. If these lines be produced they will meet at the point N. Project the points on the plan to the elevation at right angles to XY in h', j' , etc., on B.C, and $1', 2'$, etc., on AD; join $1'h', 2'j'$, etc., and if these lines be produced they will meet at the point n .



Figs. 135, 136, and 137

Complete the triangles in the plan by joining dh , lj , etc., and in the elevation by joining Dh' $l'j'$, etc. As the lines for the triangles are all of different length it would tend to confuse the drawing if their true lengths were set out directly on the plan or elevation. It is therefore wise to set them out in separate figures, one for the rolling lines, and one for the diagonal lines, the length of the curves being taken direct from the plan. Fig. 136 is a diagram of true lengths of rolling lines, and is set out as follows:—Draw a line xy , and at y erect a perpendicular yz ; from y set off on xy the lengths of the rolling lines as shown in the plan, and from y set off on yz the *vertical* heights of these lines above XY , join them as shown by lines lh , $2j$, etc., which will be the true length of the lines they represent. In a similar manner the diagram of true lengths of diagonals has been set out in fig. 137.

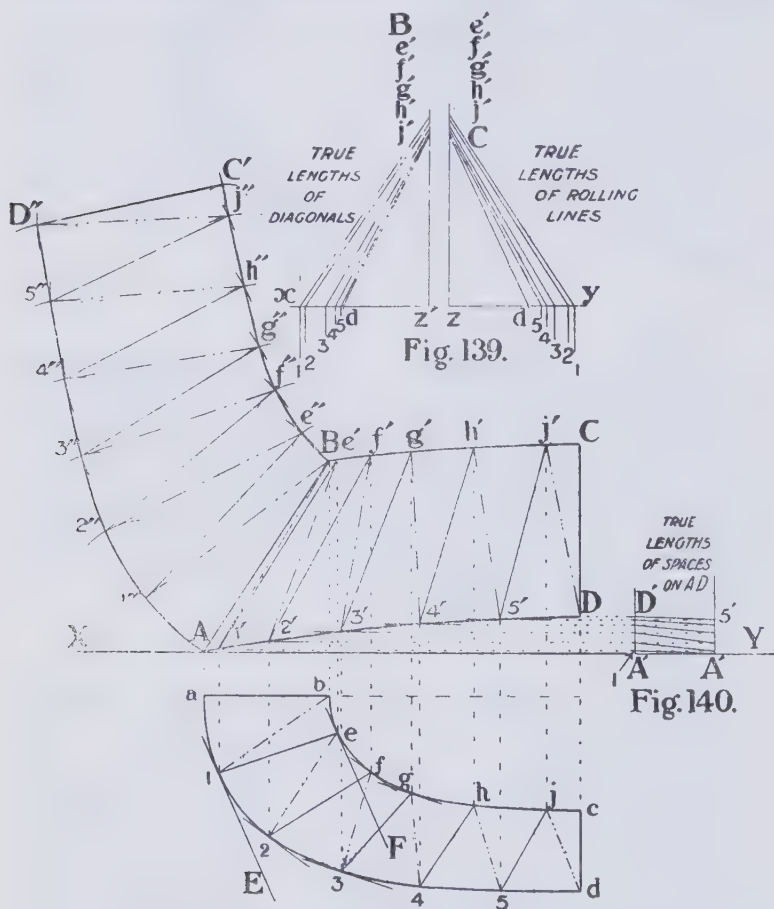
To set out the development, from B , with radius $B5$ on the diagram of diagonals, draw an arc at $5''$, from A , with radius $a5$ in the plan, cut the arc in $5''$, from $5''$, with radius $5m$ on the diagram of rolling lines, draw an arc at m'' , and from B , with radius bm in the plan, cut the arc in m'' ; repeat the process from the points m'' $5''$ to find the points $4''$ l'' and so on for the remainder of the development till $d'c'$ are found, then through these points draw the curves to complete the figure.

If the plan be examined it will be noticed the line $5b$ does not represent so much curvature as the line dh , and it is this which causes the development to become more and more inaccurate as the various points are set out, for the amount of inaccuracy in the length of $B5''$ is not so great as with $d'h''$. The plain portion of the development has been set out by Problem 53 in order to show the difference produced by triangulation, but if the plan be divided into a greater number of parts the difference would not be so great as shown in the figure, and with care a solution may be produced which will usually be quite satisfactory.

PROBLEM 84.

To develop a sloped casing, the top and bottom to be cambered to the same curvature.

Let ABCD, fig. 138, represent the elevation of half the casing above the line XY, the base AD, and the top BC being curved



Figs. 138, 139, and 140.

to the same camber, the quarter plan being *abcd*. Divide *ad* into any number of equal parts as 1, 2, 3, 4, and 5, and through

the points obtained draw lines tangent to the curve as E through the point 1, then as the top and base are parallel draw a line F parallel to E and tangent to the curve *bc* which will give the point *e*; join *1e* which will be a straight line on the figure and is a rolling line in the development. Join *b1* and repeat the process to find the points *f, g, h* and *j* which are to be joined to the base points as shown. Project the points on the plan to the elevation at right angles to XY in *1', 2', etc.*, on AD, and in *e', f', etc.*, on BC; join *B1', 1'e', etc.*, as shown. Set out a diagram of true lengths, fig. 139, where the plain lines represent rolling lines, and the broken lines represent the diagonals, the lengths in the plan being set off from *z* towards *y*, and from *z'* towards *x* respectively. The heights of the lines are found from the elevation, but are *not* to be taken as from XY, their heights are to be found by drawing a line through each point on AD parallel to XY, and the height taken from that line, thus, the height of *f'2'* for a rolling line is taken from the line drawn through *2'* parallel to XY, and the height of *f'* for a diagonal *f'3'* is taken from the line drawn through *3'* parallel to XY; these various heights are set off on the vertical lines drawn from *z* to *z'*, fig. 139, and joined to their corresponding points on *zy*, and *zx* giving the true lengths as shown by the diagram.

The curved spaces on AD and *ad* do not in either case show true lengths, and while the difference between the length shown in the plan and the true length will be very slight in the figure it would be greater if the curvature in the elevation had to be more, therefore it is as well to show how to find the true lengths of the spaces. On XY set off a space A'A', fig. 140, equal to the measured length of a space in the plan as *a1*, and at A'A' erect perpendiculars to the line XY as A'D' and A'5'. Project the points on AD to A'D', and A'5' as shown by dotted lines, and join them as shown by heavy lines D' being joined to 5' and so on, the heavy lines being the true length of the spaces along AD.

To set out the development, from B with radius B1 diagonal, fig. 139, draw an arc at *1''*, from A with radius A'1, fig. 140, cut the

arc in $1''$, from $1''$ with radius $1e'$ rolling line, fig. 139, draw an arc at e'' , and from B with radius be cut the arc in e'' . In a similar manner, from $e''1''$ find the points $2''f''$ and so on till all the points in the development are set out, when curves may be drawn from B to C' . and from A to D'' to complete the development of one quarter of the figure. If desired, the true length of spaces for the top BC may be found in the same way as from the base AD, but instead of the space $A'A'$ being the same for all the divisions as on *ad*, they will vary for the top and must be set out accordingly.

It is not wise to conclude too quickly that a problem *must* be developed by triangulation when by a careful examination it may be possible to set it out by a more accurate process; an illustration of this is given in the next problem.

PROBLEM 85.

To develop an irregularly sloping forge bonnet.

ABCD, fig. 141, represents the half plan of the base, and EFG the half plan of the top, EFG being a semi-circle, and CD described from the same centre H, whilst the arc AB is described from b with the same radius as for CD, the triangle BCF being flat. The elevation is shown in AegD on the line XY, *eg* being parallel to AD. At first sight one might reasonably conclude it is a problem for triangulation, but it is not so, and it will be found much more accurate to develop the figure by arcs described from centres which may be found, though the problem involves developing from two centres.

Divide the quadrants AB and EF into the same number of equal parts as 1, 2, 3, and 4. Join BF and produce till it meets XY in J. Join 13 and 24, and if these lines be produced they will meet in the point J. At J erect a perpendicular to XY in Jj , project B to AD in b , and F to *eg* in f , join bf and produce till it meets Jj in j . Produce Ae which will meet bf produced in j .

Produce Hf and Dg till they meet at h . The points d and j will be found to be equal in height above XY . From J with radii Jl , $J2$, and JB , draw arcs meeting AD in $1'$, $2'$, B' , and from

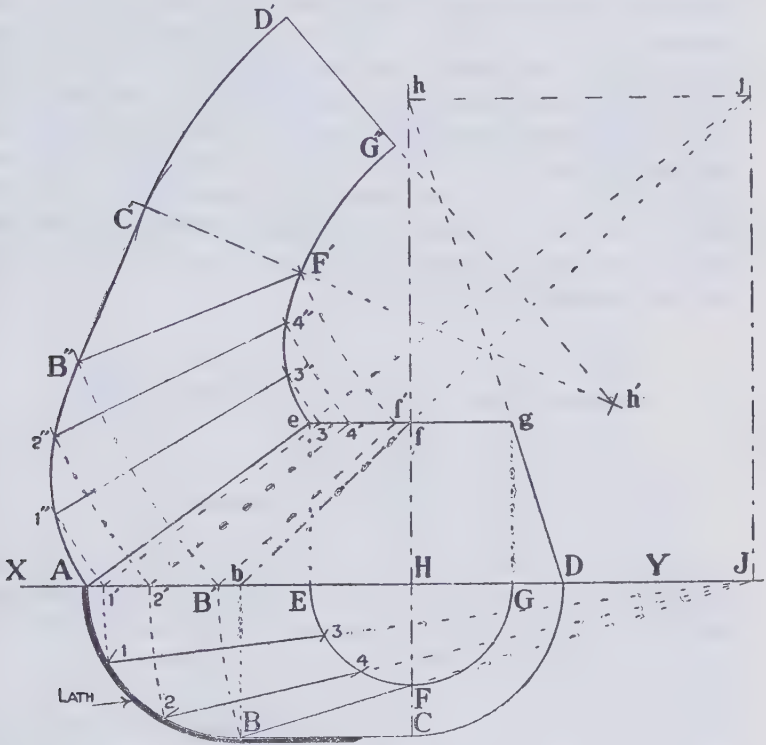


Fig. 141.

these points draw lines towards j till they cut eg in $3'$, $4'$, f' , then $1'3'$, $2'4'$, and $B'f'$ will be the true lengths of their corresponding lines in the plan.

From j as centre and radius jl' draw an arc $l'1''$, and similarly from j draw arcs from the points $2'$, B' , $3'$, $4'$, and f' . Now obtain a thin lath and bend it to the plan line ABC , keeping one end fair to A , and on it mark the points 1 , 2 , and B , then apply the lath to the arcs in the development and bend it till the points engage fairly with the arcs producing the points $1''$, $2''$, B'' , and

from these draw lines towards j till they meet the arcs for the top in the points $3''$, $4''$, F' ; these lines will be rolling lines, and with the aid of the lath the curves may be drawn in. From B'' with radius BC make an arc at C' , and from F' with radius gD , the true length of FC , cut the arc at C' ; join $C'B''$, and $C'F'$ producing the latter to h' , and from F' with radius hg , the true length of hf , cut $F'h'$ in h' , then from h' with radii $h'F'$, and $h'C'$ draw arcs $F'G'$, and $C'D'$ making them equal in length to their respective arcs in the plan. Join $D'G'$ to complete the development of half the figure in A, D', G', e . When bending the plate to shape the part $B''C'F'$ must be kept flat, C', D', G', F' , rolled conical, and the part A, B'', F', e rolled with the rolling lines as a guide till it assumes the curves shown in the plan.

ANOTHER EXAMPLE OF MULTI-POINT DEVELOPMENT.

PROBLEM 86.

To develop an irregular Y breeching.

Fig. 142 represents in miniature the elevation of the breeching; the top and base are parallel, and the parts ABC , AEF are to be flat. The top is to be a circle, and the ends of the base DE and FG are to be semi-circular and of the same radius.

Draw a centre line AB , fig. 143, at right angles to XY , and set off CD equal to the height of the figure. On each side of C set off on XY the points E and F at the proper distance required, also the points G and H . Through D draw JK parallel to XY , and set off DJ and DK equal to the radius of the top. Join KH and produce it to P . From F and H set off FM and HN equal to the radius for the ends of the base. Join DN and produce it till it meets KP in P . Join DM and JF , producing them till they meet at O . Through PO draw a line Pg which will be parallel to XY . About d describe a semi-circle $j3k$, and to the line Pg project the points M and N in m and n , from which describe quadrants fm' and hn' , join $m'n'$. Divide the semi-

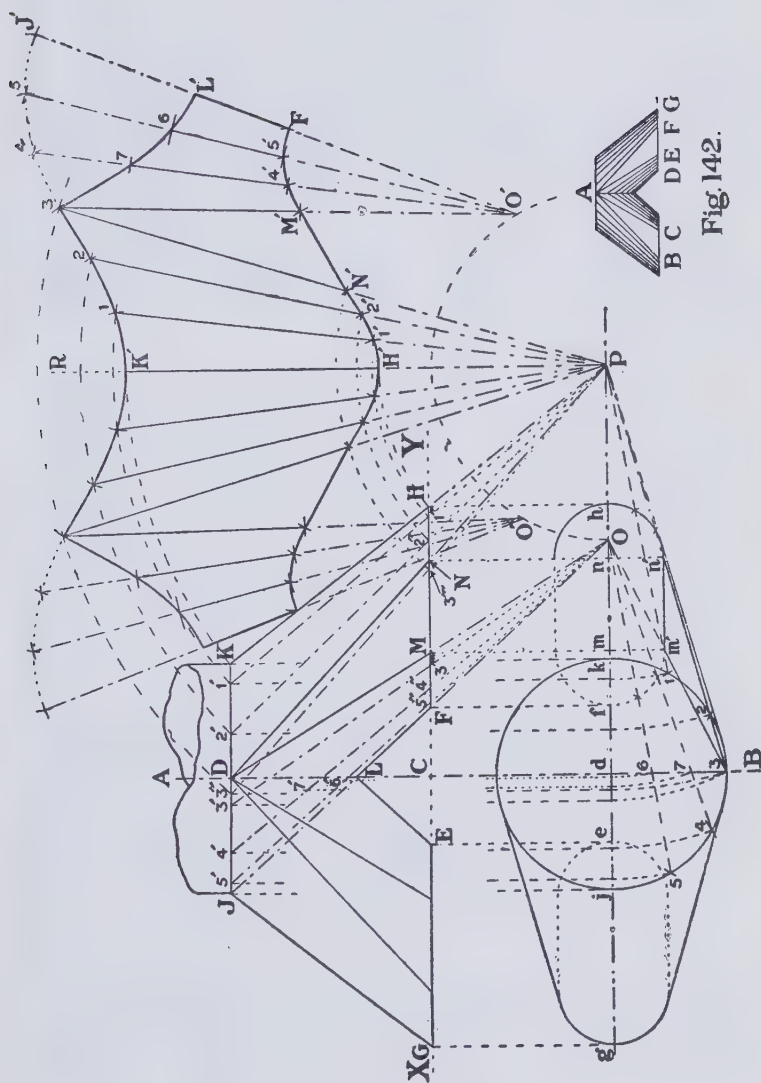


Fig. 142.

Figs. 142 and 143.

circle $j3k$ into any number of equal parts as 1, 2, 3, 4, and 5, and from 5, 4, 3 draw lines to O, the lines from 5 and 4 will cut $3d$ in 6 and 7. From 3, 2, and 1 draw lines to P, then from O with radii 3, 4, 5, draw arcs to Pg, and from these points continue the projection at right angles to XY till they meet JK in 3', 4', 5'; join these points to O, and from O again as centre and radii 6, 7, draw arcs to Pg continuing the projection at right angles to XY till the lines cut 5'O in 6', and 4'O in 7'. The lines drawn from O to the elevation as O5', etc., will be true lengths. From P with radii 3, 2, 1 draw arcs to Pg, and continue the projection to JK at right angles to XY, giving the points 3'', 2'', 1'', join these points to P which will be true lengths.

To set out the development, from P draw any line PR as a centre line, and from P as centre with radii PK, P1', P2', P3'' draw arcs as shown, and from the same centre with radii PH, P1'', P2'', P3''' describe arcs as shown, then apply a thin lath to the semi-circle in the plan and take off the correct spacing of the points k , 1, 2, 3. Bend the lath to the arcs keeping the point k fair with K' in the development so that the points on it engage fairly giving the points 1, 2, and 3 through which the curve may be drawn. Join 1, 2, and 3 to P passing through the inner arcs at 1', 2', N'. From N' with radius NM draw an arc at M', and from 3 in the development with radius 3'3''', the true length of DM, cut the arc in M'; join N'M', 3M' and produce 3M' till it meets an arc described from P with radius PO in O'. From O' with radii O4', O5', OJ describe arcs at 4, 5, J', then apply the lath in the same manner as before to determine the points 4, 5, J', from which draw lines to O'. From O' with radii O4'', O5'', OF, cut the lines in the development giving the points 4', 5', F', and from O' again with radii OL, O6', O7' cut the lines in the development in the points L', 6, and 7. Through the points thus obtained draw the curves to complete the figure. The straight lines in the development will be rolling lines, and the triangles M'N'3 will remain flat.

PROBLEM 87.

To develop a furnace crown saddle.

Fig. 144 represents an end view of the furnace, and a side view of the saddle end of the crown plate. As shown in the end view the crown plate is to be butted to the bottom plate, the crown usually being two thirds the circumference. The

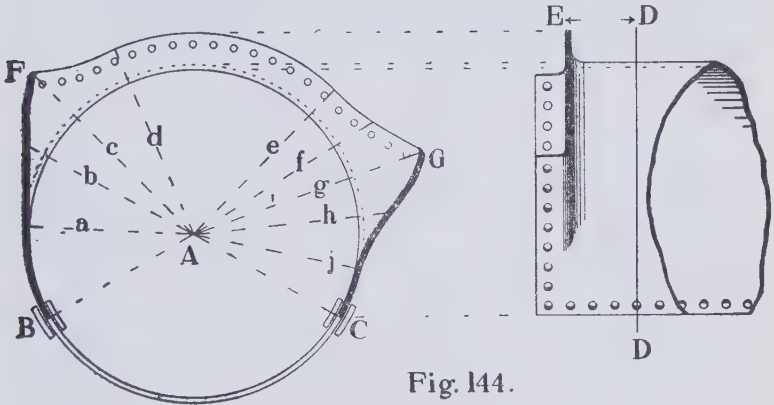
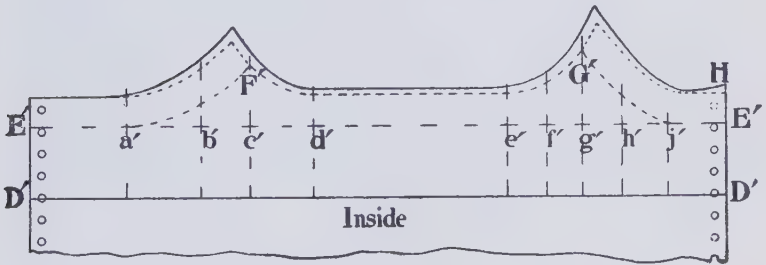


Fig. 144.



Figs. 144 and 145.

outline of the saddle having been set out as in the end view, draw any number of lines from the centre A to the outline in any position which may be considered best to indicate the varying amount of flange required, as AB, AC, a, b, c, etc., the lines c, and g indicating the greatest amount of flange at F and G. On the side view draw a line DD at any convenient position but

a known distance from the front end of the crown, and at right angles to the centre of the furnace:

To mark out the plate, fig. 145, strike the line D'D' at the proper distance from the front end of the plate to correspond with DD, fig. 144, and strike another line E'E' parallel to D'D' and distant from it equal to DE on the side view. Set off on D'D' and E'E' the divisions a' , b' , c' , etc., equal to their spacing on the end view measured around the crown plate at the centre of its thickness, and through the divisions draw lines which must be produced beyond E'E' as shown. From E'E' add on the amount of flange shown on the end view for each division line giving the dotted line $a'F'G'j'$, then from F' a' E' mark in the side flange required for the wrapper plate, and also at G' j' E'; these are both shown dotted. As there is considerable stretching in flanging out it will be necessary to add a still further amount of flange to allow for this, when the finished outline will be as indicated by the heavy line, the amount to add depends on the amount of flange required. At H extra should be allowed on because in flanging, the plate will draw away at the butt, and the extra at H may be jumped in order to adjust this when the flanging is complete, it is also advisable to leave out the end hole, shown dotted; this will not be necessary at the other side because the flanging does not extend near enough to the butt edge to effect it. The line DD is necessary to test the flanging for accuracy of length, though, of course, the front end may be taken as the guide, but a guage can be applied more quickly at the saddle end during the working of the plate.

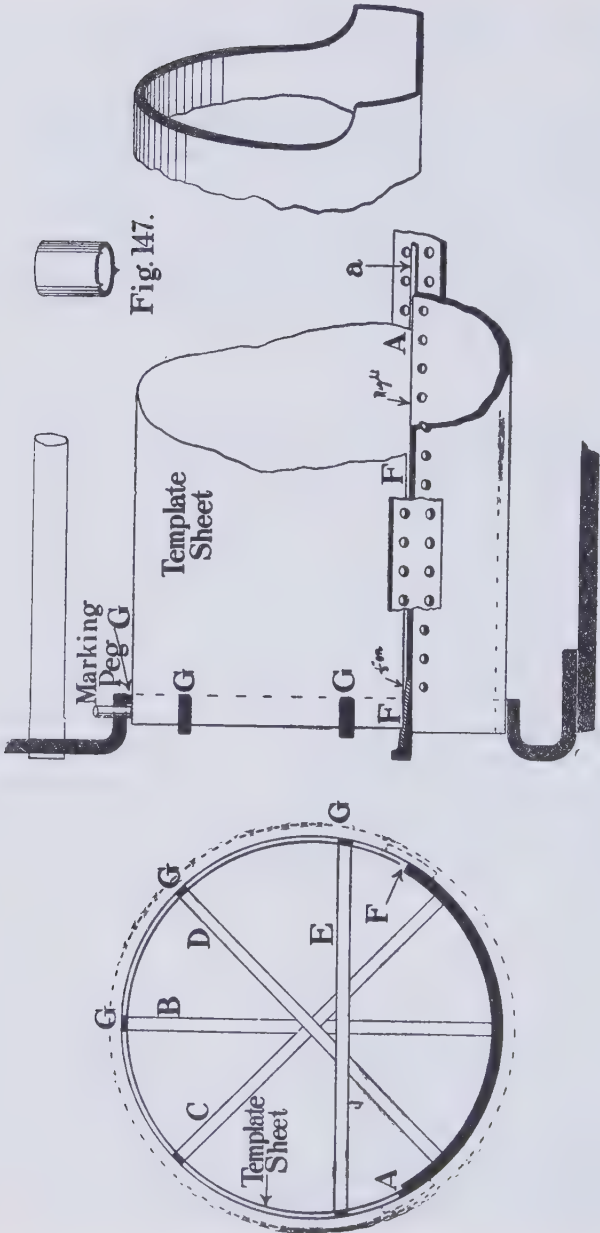
PROBLEM 88.

To mark off a plain furnace crown by a template.

It is quite a common practise when furnaces are so wasted as to be condemned, to cut the old part away about six inches from the saddle, and renew from there to the front, and with plain furnaces it is of course a great advantage to mark off the

new plate from a template so that it may be drilled before rolling to shape. It is usual to extend the lower parts of the back end so that the new crown plate takes the wrapper plates, and it will be necessary to cut the template accordingly. The template may be of sheet iron about 20 or 22 B.W.G., which will be found sufficiently pliable to set to shape easily and still stiff enough to keep its position when applied to the furnace, but it should be as free from buckles as possible; such a template may be used repeatedly, so that its initial cost will be hardly appreciable when spread over the number of plates it may be used upon.

Fig. 146 is an end view of the template in position, a part side view showing the outside butt straps on, and view of the back end showing the shape of the extensions to take the wrapper plates. The principle by which this method is carried out is to apply a template in the position of the neutral line of the plate, or in other words, at the centre of the thickness. Find the dimensions of the template at this part by measuring around the inside of the front flange, and the inside of the back end, and from these lengths deduct three times the thickness of the crown plate; this deduction will allow the template to be a little short in width as shown at F, and will admit of a wedge being inserted at each end to set the template sheet tight to its position. Measure the length, and take particulars of the extensions at the back end. Cut the template to the sizes obtained, and roll it to shape; by rolling it, it will be more easily placed in position. Put the sheet in place keeping one edge close to the butt as at A behind which has been laid a strip of wood sufficient to keep the edge of the template away from the butt strap half the thickness of the crown plate, and not so wide as to cover any of the holes in the strap, as at *a* in the side view. At both ends place shores as shown in the end view at B,C,D,E, and opposite their ends have strips of wood as at G to keep the template off from the front flange, and saddle at the back, a distance equal to half the thickness of the crown plate. Before setting the shores tightly insert a wedge at each end on one side as at F, and set the template up close to the strips of wood by lightly tapping



Figs. 146 and 147.

the wedges. When satisfied that the template is in position, tighten the shores and mark it off; this may be done with an ordinary marking peg and marking, or a scriber-peg may be used of the form shown in fig. 147, having three or four points projecting beyond the barrel, and sharp enough to make a scribe mark. Mark on the template a point at each end of the side A where the sheet touches the butt edge of the bottom plate, and on the other edge F mark at two points the amount to be allowed on to make a good butt as shown in the side view. The template being now marked it may be taken out and away to the shop where it is to be opened out flat on the furnace crown plate, after reversing the butt marks from the inside to the outside. Lay the template to the best position, and on it place some heavy weights to keep it close to the plate all over, it should also be clamped in a few places to prevent it moving when centring the holes. The plate may now be marked off by using a fine centre punch, and with a sharp blow make a mark through the template on to the crown plate. Mark the butts, and remove the template sheet. The plate will now be ready for drilling, shearing, and planing, after which it will require to be turned over for countersinking and rolling to shape. When rolling, care must be taken that it does not leave the rolls with a twist in it, to avoid a twist strike a centre line through the length of the plate before rolling, then when the plate is about the shape in the rolls lift the top roll, and set the plate so that the centre line is fair with the top roll, apply a slight pressure and pass the plate through again without quite reaching the edges when any twist there may have been in the plate will be taken out. The butt edges will now require to be drawn up, and the plate will be ready to be put in its place. It will facilitate putting in place if the crown be rolled very slightly too much.

The sheet iron method of templating may be applied to other jobs in the same way, we have even used oilcloth for the same purpose, and always had the very best results.

PROBLEM 89.

To lay out the template for the bell top of a chimney stack.

Fig. 148 is a half elevation, and quarter plan of the proposed bell top. Let it be assumed the bell portion is to be between AB and CD, the curve AC being at the centre of the thickness. Divide AC into any number of equal parts as 1, 2, and 3, and project them to XY as also the points A and C; then from E as centre and *Ec* radius describe the quadrant *cd*, and from *c* set off *cf* equal to half the width of plate at the top; join *fE*. From E with radii *Ea*, *E1'*, *E2'*, and *E3'* draw arcs meeting *Ef* in *g*, *1''*, *2''*, *3''*. From C draw CF tangent to the curve AC and meeting the centre line in F.

To set out the template, from any convenient point H on a straight line GH with radius FC draw an arc *c'c'* cutting GH in C'. From C' set off C'A' equal to CA measured along the curve. Divide C'A' into the same number of equal parts as CA in *1''*, *2''*, and *3''*, and through these points draw lines at right angles to GH, then on each side of GH set off the widths of plate as at C'*c'*, A'*a'*, and through them draw fair curves to complete the outline. The template will so far represent butt edges, but as such plates are usually lapped, one of the curves *a'c'* will require to be lengthened slightly according to the thickness of plate and the proportion the arc AC bears to a circle. The laps and top flange must also be added. When fitting the plates up it is only necessary to set the plate to the curve AC and adjust the laps *a'c'* to each other, the body of the plate not being set to the transverse curve. The marking out of the conical top K in K' will not require any explanation other than to say it may be done by describing arcs from L as centre.

Fig. 149 shows another method of making up a bell top, the form being comprised of a series of conical frustums of varying taper, each course being marked off separately and set out from

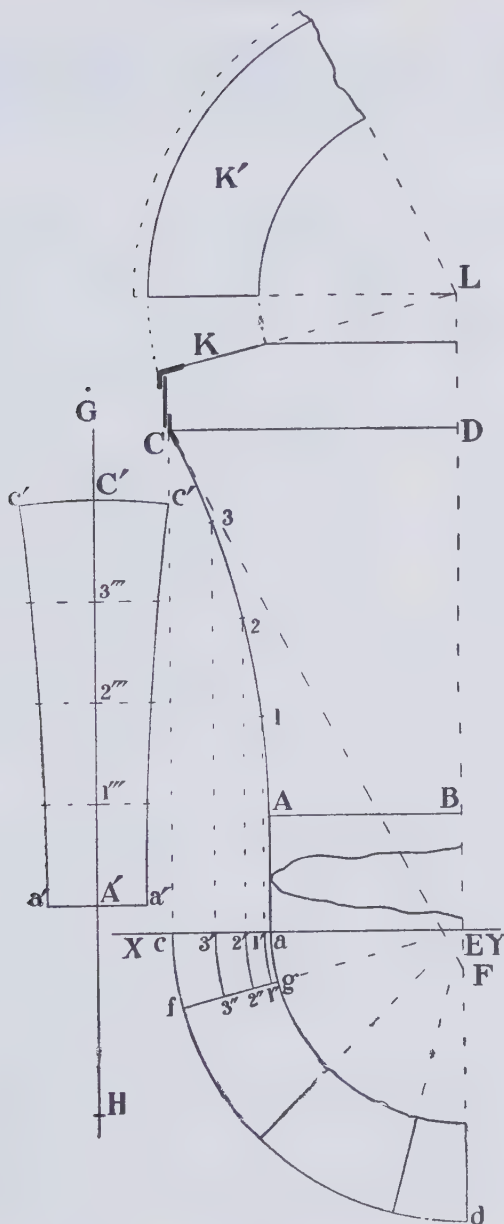


Fig. 148.

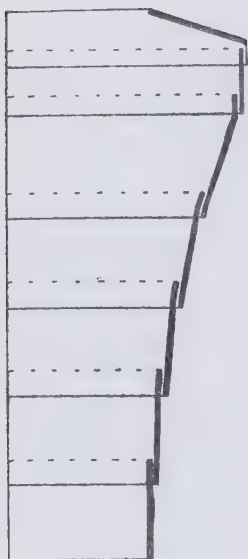


Fig. 149.

the centre line of seam holes except the top bell course which is to be set out at the top edge to the bend of the flange, and the amount of flange added afterwards.

When setting out frustums of cones which have to be made up of more than one course in the height the taper will have a considerable effect on the diameters of the circular seams, thus, in a parallel tube with more than one plate in its length the difference between the diameters of the inside and outside courses will be twice the thickness of plate, but in a cone the difference will not be so great, the actual amount depending on the taper, the quicker the taper the less the difference. The height of each course

of plate is also affected by the taper and the thickness of plate, and in view of these differences it is necessary to set out a view of the frustum showing the full thickness and the correct taper in order to ascertain the correct height of each course and the correct diameters at the seams.

Let A B, fig. 149a, represent the given height of the frustum at the centre of rivet holes, CD represent the radius of the base, and EF the radius of the top, the number of courses to be three. Join CE and divide it into three equal parts at G and H. From C and E with radius equal to the thickness of plate draw arcs 1, 1; and again with radius equal to twice the thickness draw arcs 2, 2; join E2, 11, and 2C as shown, these lines will be through the centre of thickness for the courses, and will be parallel to each other. Through G and H draw short lines at right angles to 11, these will be the positions for the rivet holes of the circular seams, for they will be at right angles to the surface of plate, then where the line through G cuts E2 will be the centre of the rivet holes for the top course, and its radius at that seam will be taken from

J, the radius for the next course at that seam will be taken from K. The bottom radius of the middle course will be taken from L, and the radius of the bottom course at that seam will be M,

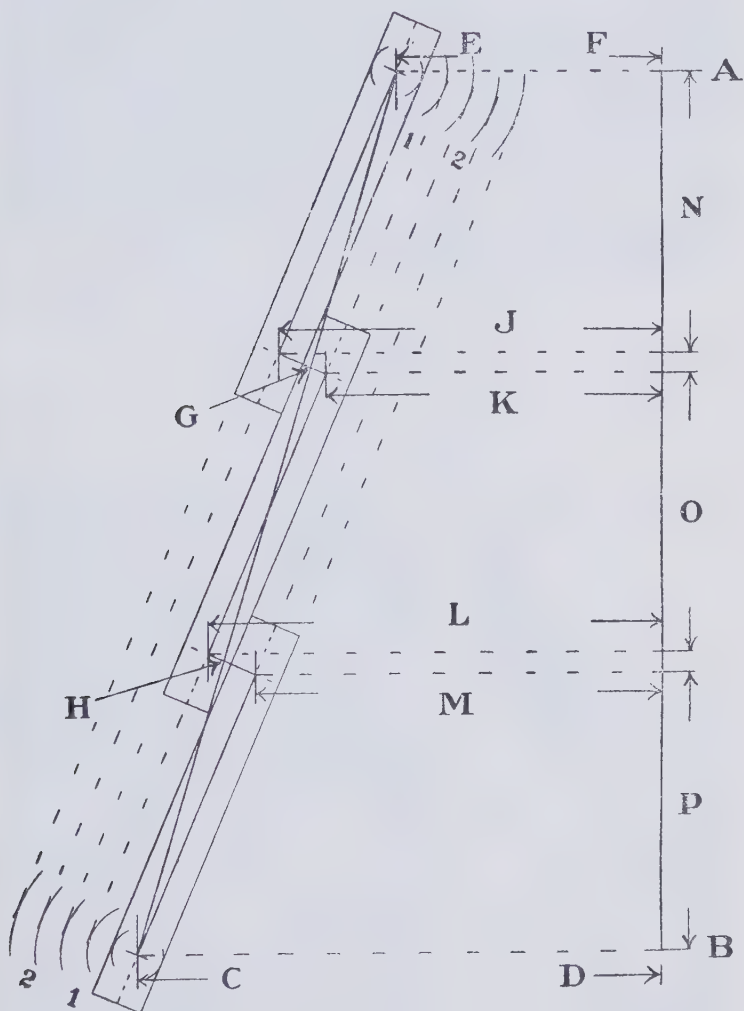


Fig. 149a.

the length of L and M being determined by the line through H in the manner same as with the line through G. It will be noticed the radii for the seam at G and H show less difference than the thickness of plate. The heights are also affected, that for the top course being N, middle course O, and the bottom course P, which added together will not equal AB, but this is due to the amount of taper and the fact that the holes are at right angles to the surface of the plate, as may be seen at G and H. The full thickness (exaggerated here) is shown to illustrate the difference in the taper of the courses as compared with that given in CD for the base and EF for the top, the centre line through the thickness produced till it meets BA produced being quite a different taper to CE and BA produced.

PROBLEM 90.

To develop a dredger bucket.

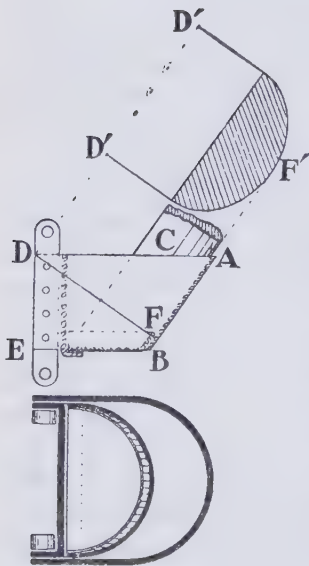
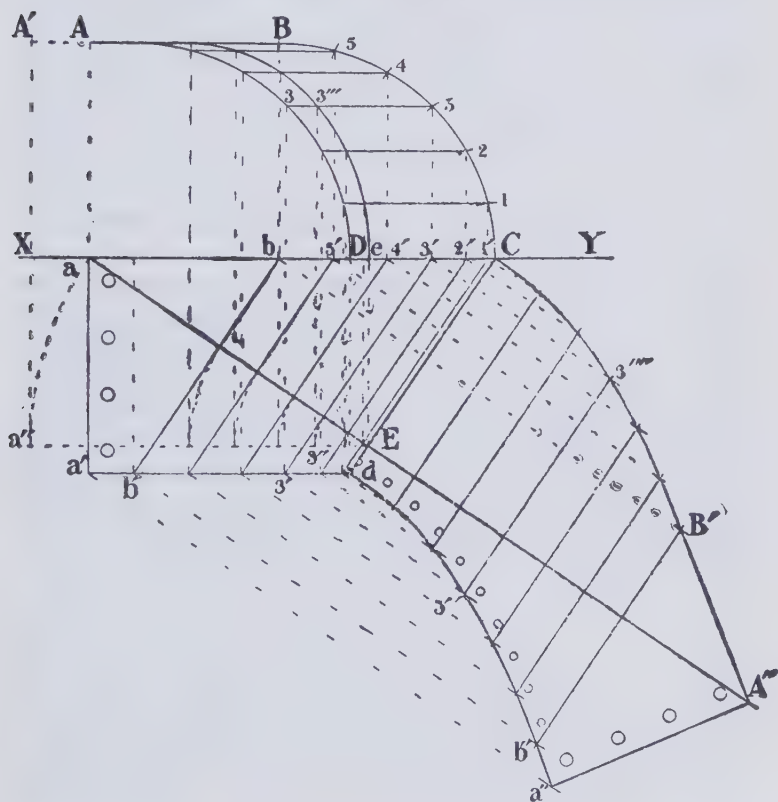


Fig 150.

Fig. 150 is a plan and elevation of a dredger bucket showing the sides extended to take the flanged back plate and the links, the back plate is also flanged at the bottom to take the bottom plate, this avoids having rivets in way of the links, and affords greater support to the bottom plate. In the figure the top and bottom are parallel, and of the same curvature; and any lines drawn on the plate parallel to the front AB will also be parallel in the development. From this it will be seen the figure is but the trace of a portion of a parallel solid which has been cut by two parallel planes as

C cut by AD and BE, the true section of which is on the line F.D. at right angles to AB, and represented above in D'F'D'; then if that portion of the solid within ABED be rolled so that the line DF traces a straight line, the lines AD, BE will trace the top and bottom edges of the figure; this rolling is termed the "expansion," and is the same principle as adopted for laying out the stern expansion of a ship. When the plate is to be rolled to shape it must be set to the shape of D'F'D', a gauge being made to that shape and applied in the position indicated by DF.

On XY, fig. 151, set out the half plan in ABCD, and below XY



set out the elevation in $aCda'$, both views to represent the centre of the thickness. It is not essential that the plan should be above XY , it could have been set out below in the usual way. Divide the curved portion BC into any number of parts not necessarily equal, as 1, 2, 3, 4, 5, and from them draw lines parallel to XY till they meet AD as 3 3. From the points on AC drop perpendiculars to aC in 1', 2', etc., and from those on AD drop lines to $a'd$, join the points on aC to those on $a'd$ as 3'3'. These lines should be parallel both in the plan and in the elevation. From a draw aA'' at right angles to Cd , cutting Cd in E , then aE will be the line of right angle section which has to be rolled out carrying with it all the points of the figure, and for this purpose it is necessary to find its true shape in the plan so that it is divided up by the parallel lines already drawn. From E draw a line Ea'' parallel to XY , and from E as centre and Ea radius cut Ea'' in a'' , and similarly from E as centre and radius to the points where Ea cuts the parallel lines, draw arcs meeting Ea'' as at 3''; project the points on Ea'' to their corresponding parallel lines in the plan as a'' to A' , 3'' to 3'', and E to e . From e draw a fair curve to A' as shown; this line will be the true shape of Ea . From E set off along the line EA'' exactly the same spacings as are on eA' measured along the curve, and through each point on EA'' draw a line parallel to Cd , and set off on each line on either side of EA'' the same length as its corresponding line on either side of Ea , as 3'''3'''. Draw the curves CB' , and db'' , and from B' draw a straight line to A'' . From a' draw a line parallel to EA'' , and from b'' with radius $b'a'$ cut the line in a'' , join $a''A''$ to complete one half of the expansion. The parallel lines in the lay out are rolling lines, and the plate must be rolled to the shape of eA' along the line EA'' , the portion $B'A''a''b''$ remaining flat.

PROBLEM 91.

To lay out a sloping companion-way.

Let $ABCD$, fig. 152, represent a side elevation of the companion-way, the half end views being aeB and dfC , and the quadrants

eB and fC described from E and F with the same radius. The principle applied to the previous problem serves also for this, the

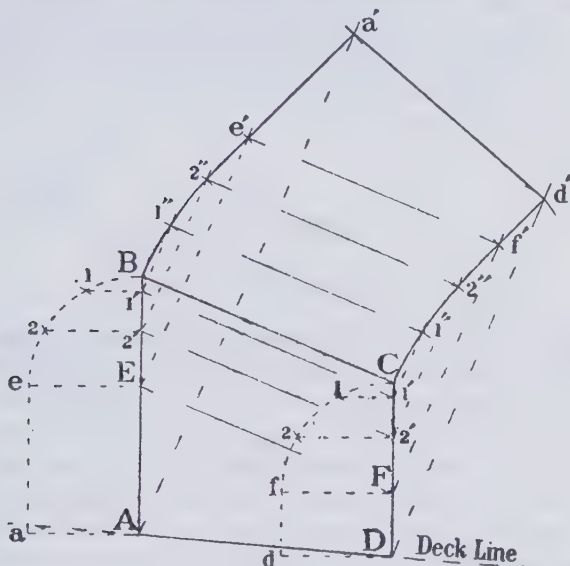
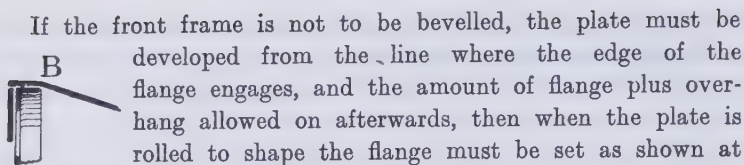


Fig. 152.

fact that AD is not at right angles to BA or CD does not make any difference.

Divide the quadrants Be and Cf into the same number of equal parts as 1, 2, and project the points to BE and CF at right angles to BA and CD in $1', 2'$. From $1', 2', E, F, A$, and D , draw lines at right angles to BC , and from B and C with radius $B1$ step off from line to line the points $1'', 2'', e', f'$. From e' with radius EA cut the line drawn from A in a' , and from f' with radius FD cut the line drawn from D in d' ; join $a'd', a'e', d'f'$, and draw the fair curves from B to e' and C to f' to complete one half the development in $Ba'd'C$. Mark in the holes for the foundation angle the root of which will be on $a'd'$, and mark the holes for the end frames remembering to allow the plate to project beyond the root of the frames equal to the thickness of the end plates.



If the front frame is not to be bevelled, the plate must be developed from the line where the edge of the flange engages, and the amount of flange plus overhang allowed on afterwards, then when the plate is rolled to shape the flange must be set as shown at Fig. 153. B, fig. 153. The parallel lines $1'1''$, $2'2''$, $e'f'$ in the development are rolling lines.

PROBLEM 92.

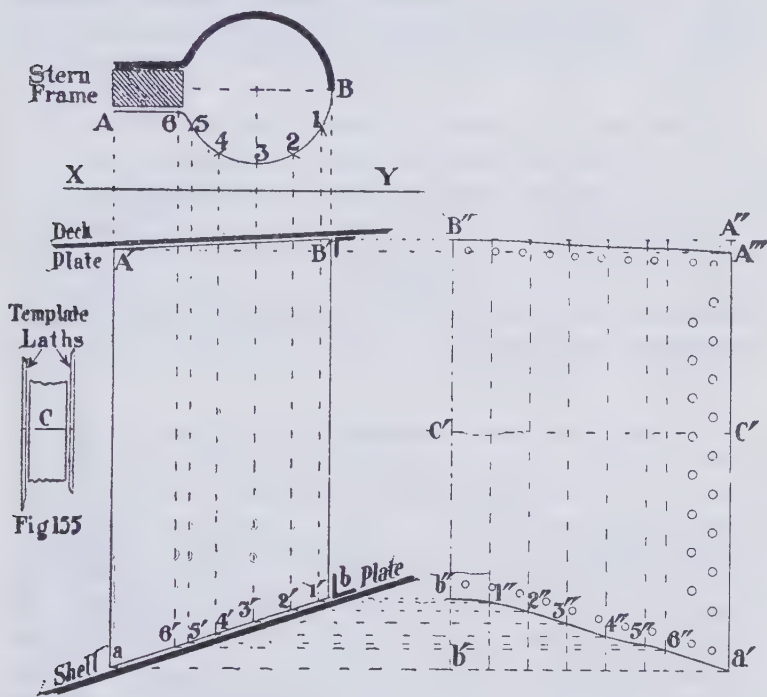
To lay out a rudder tank.

A rudder trunk is a tube through which the shank of the rudder is passed to receive the tiller above the deck, it is attached to the stern frame in the manner shown in the plan above XY, fig. 154, and it is secured to the shell plating by an angle iron connection which is usually fitted in halves butted at b , and the fore ends butting closely against the transom floor plate. The angle connection at the deck is usually in one piece around the tube, the fore ends being turned to form a connection with the transom beam, this admits of caulking the tube and preventing water entering the ship through the rudder aperture.

Draw a half plan of the tube AB above the line XY, the fore and aft centre line being parallel to XY, and AB representing the centre of the thickness. Divide the circular portion into any number of equal parts as 1, 2, 3, 4, 5, and also mark the limit of the flat surface at 6. Draw the elevation of the tube below XY in $A'B'ba$, the edge $A'a$, and the back $B'b$ being at right angles to XY. The tube should be kept a little short at the ends in order to allow the caulking to be done with the best effect, a quarter of an inch will be found sufficient. Project the points on AB to the elevation by lines meeting ab in $1'$, $2'$, etc.

Draw $B'A''$ and aa' parallel to XY, and set off $B''A''$ equal to BA measured along the curve, at the same time set off the divisions. From a' set off the divisions to b' and join them to

those on $A''B''$, $B''b'$ being at right angles to aa' . Project the points b , $1'$, $2'$, etc., by lines parallel to XY till they cut their corresponding lines in the development as b'' , $1''$, etc., and through them draw a fair curve from b'' to $6''$, the line from $6''$ to a' will be straight. The top may be set off in a similar manner, or the



Figs. 154 and 155.

lengths of lines may be taken from the elevation and set off on those in the development through which the top edge may be drawn giving the half plate as $B''A''a'b''$.

When marking the template laths for the stern frame holes, it is not well to depend on the holes being alike at both surfaces, and therefore a template should be made for each side, but before marking them scribe a line square across the stern frame as at

C, fig. 155, and when the templates are applied copy the touch mark on to the edge of the laths as shown, and when marking the holes on to the plate at A''a', copy also the touch mark at C', then from C' strike a line through the plate parallel to XY and apply the other template fair to the touch mark when the holes may be marked in their correct positions. Mark in the holes for the top and bottom angles, and proceed to punch and shear the plate.

When bending to shape, the edges should be bent as shown



Fig. 156.

in fig. 156 before rolling the body, care being taken to have no twist when in the rolls.

PROBLEM 93.

To lay out a stern expansion.

The laying out of a stern expansion is one of the most interesting problems in the construction of a ship, and one that does not always fall to the lot of the plater to set off. The development is usually done in the mould loft, and templates are issued to the plater from which he makes the plates, frames, beams, gussets, etc., for the whole expansion from the transom frame on one side to the transom frame on the other side. The plating below the knuckle line, called the counter, is done after the expansion is in position with the cant frames attached to the transom floor, but the true shape of the cant frames has to be found in order that the shell plating shall be in that symmetrical form necessary to meet the forward part of the hull.

The data supplied for marking out the stern expansion will be a plan and elevation of the knuckle line extending some distance forward of the transom frame, a plan and elevation of a water

line through the counter from which the true shape of the cant frames is found, the plan and elevation of the transom frame from the knuckle line to the centre line of the ship, an elevation of the top edge of the expansion, an elevation of the stern rake, and the number of cant frames required on each side, if there is to be a deck in way of the expansion it will be shown in the elevation as representing the position of the beams, or ends of the frames, the beam rise will also be given. From this the remainder may be ascertained.

Before attempting to work out this problem, it is advisable to read up Problem 90, which deals with the principle by which the stern plating is set off, and will be an advantage to the reader inasmuch that it will not be necessary to complicate this problem unduly by repeating the principle dealt with in the problem named. It will also assist somewhat if the fig. 157 be examined carefully in conjunction with the references thereto.

Draw a line XX, fig. 157, and from any convenient point F draw a line at right angles to XX to represent the centre line of the ship, and from F set off FG equal to the knuckle line position of the transom frame. Draw in the knuckle line AA passing through G. From a point *f* on XX set off *fg* equal to the height of the knuckle line on the transom frame, and through *g* draw in the elevation of the knuckle line A'A'. Draw the elevation of the top edge BB; the deck line, that is, line for tops of beams, in CC, and the stern rake A'B. From A', the junction of the knuckle and rake lines, draw a line A'D at right angles to the rake line A'B, this will be the section line, and also from A' draw a line A'D at right angles to XX, this will be the section line brought into the horizontal plane from which the true shape of A'D' is to be set out. At about the centre of the elevation draw a water line E; it is by the use of this line that the curvature of the cant frames is found, and touch points set off on the frames by which to mark the frame holes on to the expanded plates. All horizontal lines are called water lines, and all fore and aft vertical lines are called buttock lines. Through any number of

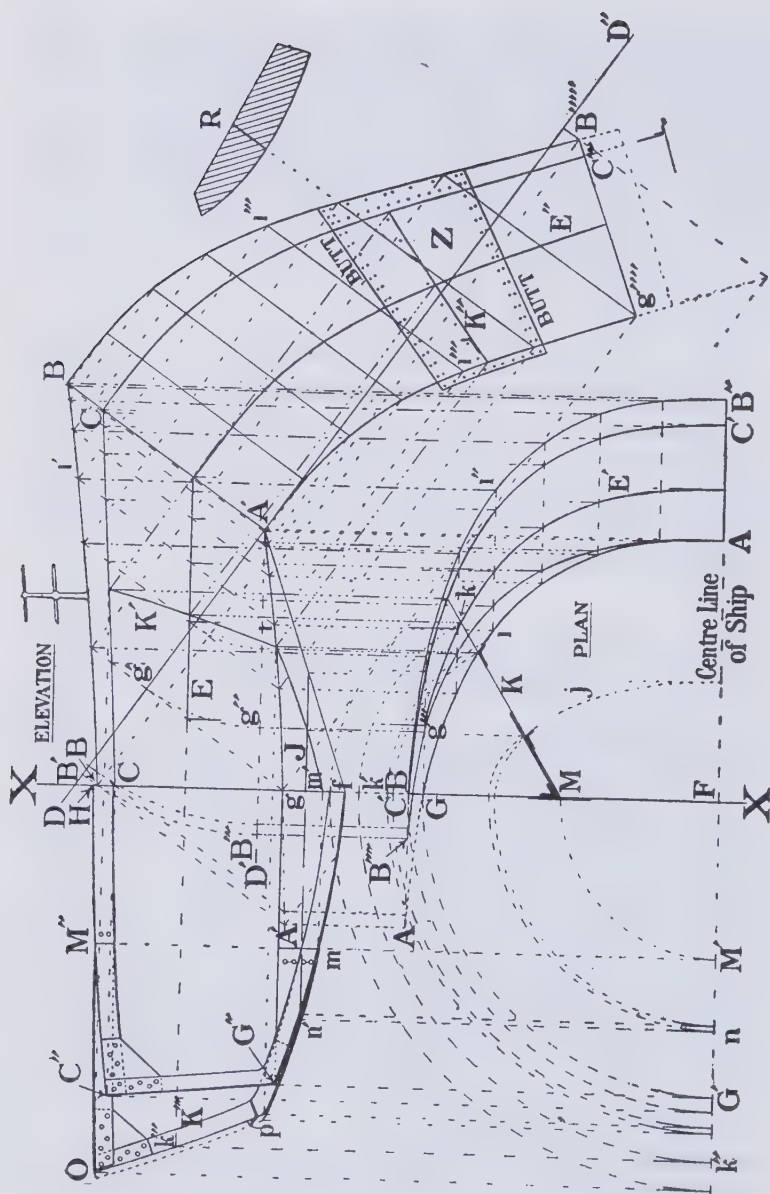


Fig. 157.

REFERENCES TO FIG. 157.

PART.	ELEVATION.	PLAN.	EXPANSION.
Transom Frame	<i>Cgf</i>	<i>C'GF</i>	<i>C''g''</i>
Moulding Line	<i>BB</i>	<i>BB''</i>	<i>BB'''</i>
Deck Line	<i>CC</i>	<i>C'C'</i>	<i>CC''</i>
Water Line	<i>E</i>	<i>E'</i>	<i>E''</i>
" " (counter)	<i>J</i>	<i>j</i>	
Knuckle Line	<i>A'A'</i>	<i>AA</i>	<i>A'g''</i>
Cant Frame	<i>K'</i>	<i>K</i>	<i>K''</i>
" " (true shape)	<i>K''</i>		
" " (bevel)	<i>p</i>		
Cant Beam	<i>OM''</i>		
Section Line	<i>A'D, & A'D'</i>	<i>AB''</i>	<i>A'D''</i>
Rolling Mould .....	.....	.....	<i>R</i>
Counter Line (fore and aft).	<i>A'f</i>	<i>AF</i>	
A Plate marked off .....	.....	.....	<i>Z</i>

points on the knuckle line in the *plan* draw lines parallel to the centre line of the ship and extending well towards the stern, a line should be drawn through the point G. Project the points to the elevation of the knuckle line parallel to XX, as 1 to 1', then from the points on the knuckle line in the elevation draw lines parallel to the *rake* line A'B till they cut the top edge line BB as at 1'. Through B on XX draw a line at right angles to A'D meeting A'D in B', and the knuckle line in A'. Project all the points on the top line to the plan till the projectors cut their corresponding parallel lines as at B'' and 1'', and from A at the forward end of the knuckle line in the plan projected from A' draw a line parallel to the centre line of the ship till it cuts XX in B which will be the plan of the top edge of the expansion above the transom frame. Draw a fair curve from B'' to B passing through the intermediate points on the parallel lines as at 1''; this curve will be the plan of the top edge. In exactly the same manner the plan of the deck line and the water line may be found in C'C' and E' respectively. From A', at the lower point of the stern rake line with radii to each point on A'D where the parallel lines intersect it draw arcs till they meet A'D' as B' to B'', and from these points on A'D' draw projectors till they cut their respective parallel lines in the plan, as B'' to B'', and g' to g'' and g'', then draw a fair curve from A in the plan to B'' passing through the intermediate points on the parallel lines, as g'', which will be the true shape of A'D, the sectional line.

Before dealing with the frames we will set out the expansion of the plates in the following manner:—Produce DA' in A'D'', and from A' set off exactly the same spacings as are on the true section line AB''' measured along the curve, and through the points thus found draw lines parallel to the rake line A'B; then from the points on the top edge line, deck line, water line, and knuckle line in the elevation draw lines parallel to DD'' till they cut their corresponding parallel lines in the expansion as 1''1'', B''', and g'''. Through the points obtained draw the fair curves for the top edge, water line, etc. Join B''' g''' which will be the position for the transom frame. As it is usual to

have the termination of the expansion in the first space forward of the transom frame, the curves for the top, deck, and knuckle should be produced accordingly, as shown by the dotted extension, The plating will now be set out for half the stern from the centre to the transom in $A'BB''' g'''$.

From F with radius FG draw an arc GG', and from g draw a line at right angles to XX, then a line drawn from G' parallel to XX will meet that from g in a point G'' which is the knuckle position of the transom frame; from G'' trace in the given true shape of the counter portion of the frame to f. From F with radius FC' on XX in the plan draw an arc to FG' produced, and from that point draw a line parallel to XX till it meets a line drawn from C on XX and at right angles to it in C'', join C''G'' which will be the continuation of the transom frame. Set off CH equal to the beam rise, and draw in the given curve for the beam in C''H. Draw the water line J through the counter in the elevation, and draw its plan j. Set off on FG the positions for the frames, these are taken as at the heel of the bar, and are always straight in the plan, their positions being set so as to be as evenly disposed as possible on the expansion plates. We will suppose a frame is required at K. Project the points where it engages with the water line j, knuckle line, water line E', and deck line, to the elevation, and from F with radius FM draw an arc MM', and project M' to the transom frame in m, then from m draw a line at right angles to XX till it meets XX in m' which will be the elevation of the lower point of the frame K; from m' trace the position of the frame through the points projected from the plan when it will be seen the frame shows a slight curvature both in the counter and in the expansion above. From M with radii to the points on the frame where it cuts the water line j, the knuckle line, water line E', and the deck line, draw arcs to XX as k to k', then from F with Fk' radius draw an arc k'k'', and from k'' draw a line parallel to XX till it meets the water line E produced at k''', which will be the point on the true shape of frame K' where the water line E crosses it; the position of the knuckle point, and the deck point are found in the same manner

by which the top portion of the frame may be drawn showing the slight curvature required. The true shape of the upper portion of the transom may be found in the same way, for it will not necessarily be straight. The point k'' will be a touch point on the frame for the purpose of transferring the frame holes to the plates, and the same water line gives a point on the transom frame, in fact on all frames. Through m draw a line parallel to XX up to the beam of the transom, this will indicate the termination of the frame K on the transom floor, and also the termination of the beam for K on the transom beam. The point n' on the water line J is found in the same manner as the point k'' , and then the lower portion of the frame K may be drawn from the knuckle through n' to m . To find the bevel of the frame, draw in a section of the bar at the knuckle line in the plan, and from M and F as centres project the edge of the flange till the point p is found on the true frame shape, trace in the edge of the flange here as shown dotted, then at any part draw a line square across the web of the bar, and from the heel as centre with radius equal to the width of the shell flange draw an arc, and where the arc cuts the edge line will indicate the bevel as shown in section. If required, the cant floor gussets may be all kept at the same level as the transom floor by tracing the line gG'' on to each frame in succession, thus giving a level flooring to a storeroom.

To set out the frame position on the expansion project the points in the elevation where the frame heel engages with the knuckle line, water line E , and the deck line, to the expansion by lines drawn parallel to DD'' which will show a slightly curved line for the frame position on the expanded plates. After the frame is punched, make a mould from the shell flange and also mark on it the position of the water line, then apply the mould to the expansion, setting the touch mark fair to the expanded water line, and mark off the frame holes on to the plate. It may be as well to remark that while the transom frame flange is forward, the cant frame flange is aft so that all bevelling is open.

Set off the positions for the butts of the plates, and if separate moulds are to be made for each plate, care must be taken to have

a rolling line to each on which must be applied the rolling mould. The rolling mould may be in the form shown at R, and is made from the true section line AB"" at the position the plate has to be when in its place, and on it must be a line which is to be on the rolling line at all times. The bottom flange must be added, and the holes for the shell plates put in, also the moulding holes and those for the rail stanchions and gunwale angle. The moulding should be bent on edge to the shape of the top expanded line before bending to the shape of that line in the plan. By following this problem carefully, all parts in connection with the stern expansion may be made and assembled in position, the adjoining plating being done afterwards.

PROBLEM 94.

To mark off plates for punching before flanging.

As the method for marking off flanged plates applies to all straight flanged work, it will only be necessary to deal with one kind of plate to explain the method, and for this purpose we will take the keel plate as the example. Make a shell mould, and a keel mould, as shown in fig. 158, the parts at A and B being cut away to clear the bend of butt straps if they happen to be on the adjoining plate. The ends may also be either short and

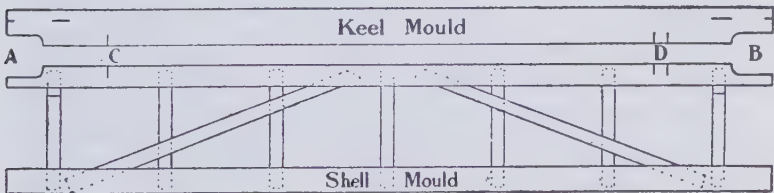
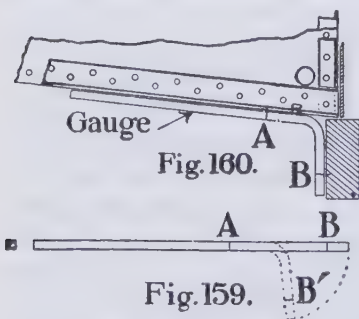


Fig. 158.

the correct butt length measured on, or they may be left long so that the butt edge of the next plate may be marked on the ends of the template, and further, if the butt strap is already on the next plate, a batten may be attached to the extensions at A and B on which to mark the holes, but in marking the plates for a whole keel strake the butt straps will in no case be in position, and the cut away will not be necessary. At each end make touch marks as at C and D exactly opposite each other, and have them on both sides of the templates.

The next thing is to have two gauges, or set irons the *same thickness as the plate to be used*, and on them make two light chisel marks as at A and B, fig. 159, their distance apart to be carefully noted, we will say they are a foot apart, now bend the gauges in the same machine as the plates have to be bent, or at any rate to the exact curvature the plates have to be, as shown by the dotted lines, the chisel marks will then be in the new position



Figs. 159 and 160.

indicated at A and B'. If the plate to be marked off is the same set at each end, one gauge only will be necessary, but if the plate is towards the bow or stern and there is a difference in the set of the plate as between one end and the other, it is best to use the two gauges. Let it be assumed the plate is at the amidship section; apply a gauge to the position the plate has to be, and opposite the chisel marks make marks on the frame and keel, fig. 160, this to be done at both ends of the plate position. On the keel strike a line through the two marks so that it extends beyond the ends of the plate. Apply the templates as shown in fig. 161 the two being placed in position together, and the guide marks at C and D, fig. 158, exactly opposite. Proceed to mark off the holes, and copy on to the template the marks on the keel and

frames which were taken from the gauge iron, note also the correct landing for the edges, and the position of the butt for the next strake of plates. If an adjoining butt strap is on it will be necessary to tack on a batten for the holes and at the same time giving the butt length. The templates may now be taken down and away to the shop to be marked on to the

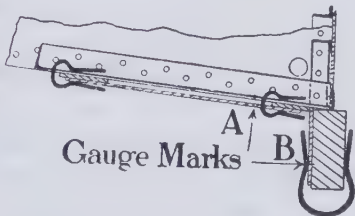


Fig. 161.

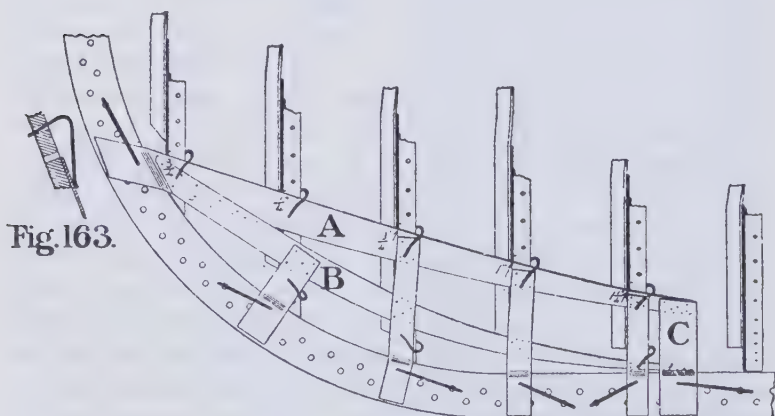
plate. Before laying the templates on the plate, reverse the reference marks so that they will be on the upper surface when marking. Lay the keel template on first if the sheared edge is up, but if it is down, lay on the body template first; this is, of course, assuming the plate is to be inside at the landing, as in the figures. Set the template to the correct position as regards lap for the holes and clip it firmly, mark it off, and through the gauge marks drive a centre punch, now apply the body mould so that the touch marks C and D are exactly opposite, and the gauge marks A exactly one foot from the marks B on the keel mould; the template being set fair, clip it firmly along the landing edge, and remove the keel mould. Mark off all holes and mark the correct landing edge and butts, then through the gauge marks drive a centre punch. The template may now be taken off, and the space where the butt of the next strake is to be must be chalked so that the puncher will put in the extra holes required. Strike lines through the centre punch marks, and at about the middle of the plate scribe the position and shape of the bend required in relation to the gauge lines; if one end has to be a different bevel to the other, the set must be marked at each end accordingly, then when the plate is to be bent, the proper set will be found marked on it, and no error can occur, but it should be noted the set marks on the plate should always be made from the outside of the gauge, then the one who has to bend the plate will set the inside of his gauge to the same mark and be able to apply it to the outside of the plate. The same gauges may be used repeatedly by adjusting the bend to the angle required before marking the nicks on to the keel and frames.

PROBLEM 95.

To mark off, and bend a forefoot plate.

It seems quite a common practice, especially in ship-repairing, to set forefoot plates to shape and put them in position to mark off, the plate being set over the old one if it is not too badly damaged, or sometimes an old plate is cut to the shape of the body part and rolled to the twist, then the new plate is set over that and flanged, no holes being put in the new plate. It will be found much more satisfactory to template the plate off from the ship, and if the following instructions be carried out, the making of such a plate will be a much more simple matter than by the old method.

Let it be required to make an inside forefoot plate, the adjoining plating being not yet made. Clip a template batten to the frames as at A, fig. 162, extending from the proposed butt to the stem, the batten to be scored on the inside in line with the inside



Figs. 162 and 163.

edge of the stem bar, thus allowing it to bend and the stem part to lie flat on the stem, where it is clipped by means of a clip dog of about half-inch round iron as shown in fig. 163. The batten should be allowed to take a natural position without any attempt to follow the line of nicks on the frames, and should have no buckles. In a similar manner clip a batten B, extending from the lower part of the butt to the stem, but not taking it. The batten C for the butt, scored to take the stem, must now be tacked to A and B, and the fore ends of A and B tacked together; this should only be lightly done. The template must now be taken down and laid on a flat surface, and if there is any buckle, one of the joints must be loosened so that the template will lay flat, when it may be securely tacked and replaced in position. The frame battens are now attached, the inside of each being scored so that it bends and takes the stem in a natural position. The template may now be marked off including the stem holes covered by the mould, and the amount to be allowed on from the edge of A to the nicks on the frames must be marked on the mould, also

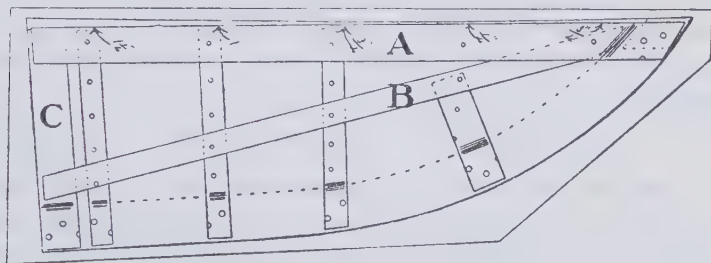


Fig. 164.

the inner edge of the stem. The template may now be taken down and a separate mould made for the stem holes, also the gauges or sets made for bending to shape, the moulds may then be taken to the shop, and the body mould marked off in the same manner as an ordinary plate after reversing the allowance marks. Fig. 164 shows the plate with the template on it and the line for the bend marked in, and also the top and stem edges. All the

holes should be marked and punched as shown on the template, and the holes for the butt; the landing holes will, of course, be marked and punched from the other side. When turning the plate over, reverse the bending line, and lightly centre mark it at points about a foot apart. After the plate has been countersunk

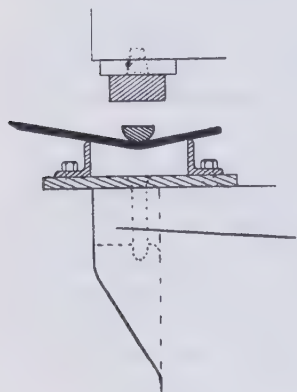


Fig. 165.

and planed it is ready for bending to shape; this may be done cold at the punching machine so far as the flanging and frame set are concerned, the press being adapted for this purpose in the manner illustrated in fig. 165, but it is practically a waste of time to attempt to set the plate entirely to the required shape at the press, because in the process of twisting the body part, the flange has to stretch, and this is best done at the furnace, in fact, must be so done. When flanging, it is best to flange a little more bevel than

shown by the gauges, so that in twisting, the root or heel of the bend may bear on the slab and allow the flange to be levelled by the flatter without the necessity of using the fuller to set down the bend.

The plate being ready for twisting, hold the butt gauge with the stem part level on the slab, and the body part rising from it, then at the position for the bottom edge of the plate put a pin in the slab, or an angle lug with a dog to hold it as in fig. 166, and stand a strong pinch bar in the slab in such a position that when it is strained as though the plate were against it, the plate landing-edge mark on the gauge will be fair with the bar. Place the plate in the furnace and when heated draw it out and lift the fore end, tipping the plate the while, till the butt end is in the position previously arranged with the gauge; put a good dog on the flange at the butt end, and let the fore end go; the plate may now be easily twisted till the flange lies level, following along with more dogs as the flange takes its level position on the slab; a

good effect is produced by having a slab hook inserted through which a bar may be placed, then the bar may be pressed down on a block of wood as shown in the figure, till the plate is level all

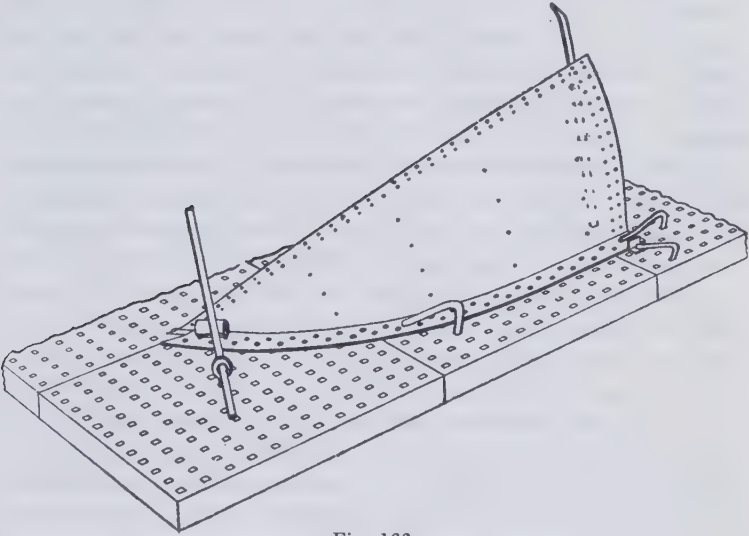


Fig. 166.

along the flange. When cold the stem mould may be applied to the holes already in the plate and the remainder marked and punched.

Sometimes the forefoot plate may be templated for all holes to be put in before bending, but such plates are usually for a long easy forefoot where the curvature in the stem is not great, then by adding more battens in the manner done for the frame holes, keeping them apart on the stem about an inch, and each batten not to take more than about three holes, the whole plate may be marked off direct, but where the curve is quick we prefer to have a separate template for the stem and apply it after bending as explained.

In reference to the use of the punching machine for bending plates it may be mentioned the press is now adapted for many

purposes, such as for bevelling angle bars, joggling landing edges, fairing damaged plates, setting pipe casings to shape, setting bilge plates that are too long to be rolled, twisting plates when they are too long for the rolls, etc., etc., and in almost every case the work is done cold, the material being steel. For the various jobs that are to be done at the punching press suitable gear is of course necessary, and that illustrated in fig. 165 may be used for flanging the top tool taking the place of the punch to have a base about five inches square, and to press on a piece of solid moulding about eight or ten inches long to which is welded a shank for holding and guiding the piece, then as the bending proceeds by easy stages packing laid on the moulding will cause the plate to be pressed lower till the desired angle of bend is obtained; the figure shows about sufficient bend for the first press, the angles being set apart about nine inches, but may be adjusted either closer or further apart according to the radius the bend has to be. It is also sometimes necessary to use a pressing piece with a square corner instead of moulding, such as when flanging light plates; then a piece of angle bar may be used with the heel to the bend. When twisting plates at the press the angles and base plate should be set at a skew as it were, to suit the required twist, and the plate worked backwards and forwards as though a landing edge was being punched, then as the plate is pressed to the frame set—for all twisted plates have frame set, more or less—the twist will be put in the plate at the same time.

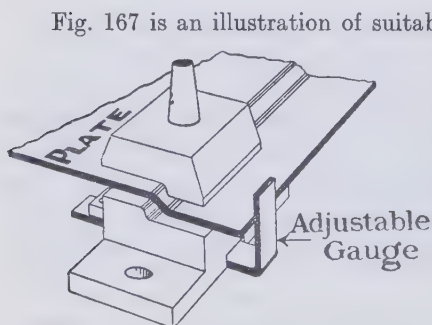


Fig. 167.

Fig. 167 is an illustration of suitable top and bottom blocks for joggling plates, the top piece taking the place of the punch, and the bottom piece taking the place of the die, and whereas the top is always in the same position, the bottom block may be made with long holes in the base to allow

of adjustment according to whether the joggle has to be easy or sudden. The step in the blocks is usually made equal to the depth of joggle required for shell plates, say nine-sixteenths of an inch, and if a recess is arranged through the bottom an adjustable gauge may be set for the width of the joggled part, the front end of the gauge being bolted to a projecting portion of the base block. The plate should be slung in the crane by means of a bridle sling, fig. 168, because when the plate is being pressed the back part of the top block touches first and tips the plate, and if ordinary hooks are used they may become disengaged and let the plate fall.



Fig. 168.

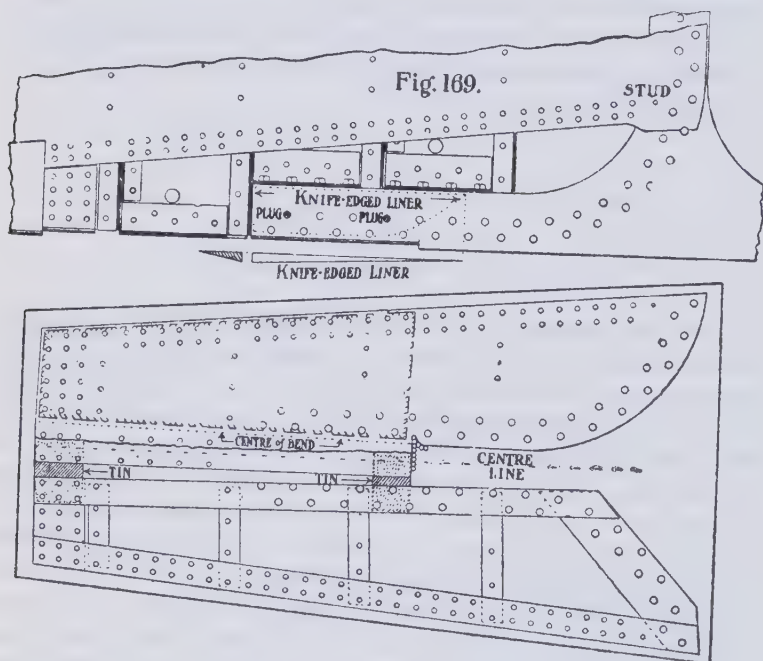
PROBLEM 96.

To mark off and bend a stern shoe plate.

A very common form of stern is shown in fig. 169, the stern frame being shaped to allow the shoe plate to butt against a step or check, the plate forward of the step being continuous from side to side. It is usual to make the stern frame parallel fore and aft, the lower corners being rounded to receive the plate, and the tapered liner required to make up the deficiency as between the frame and the plate is made after the angle frames are in position together with the intercostal plates and lugs, the lugs being studded to the stern frame as shown. This liner will be tapered from forwards towards aft, and from the top edge to the bottom, and when the template for the shoe plate is being made these liners should be held in position by means of wooden plugs driven in two holes, the ordinary frame liners may be similarly secured before the plate is put in position.

In making the template care must be taken that the principle of working to the centre of thickness is strictly followed, and to do this make an ordinary template for each side, the lower edge only just taking the holes in the stern frame and the butt strap, and the

frame battens to be applied outside the seam and bottom battens ; tack the template except at the lower part of the butt. Place a batten in position under the stern frame ; this to be an exact fit between the step and the butt, and no wider than the flat portion ; it may be kept in position by two light shores. Shape a strip of tin, about six inches wide, to the position of the *centre of the thickness of plate* at the step, and long enough to allow of it being securely tacked to the side battens, and at the butt end apply a



Figs. 169 and 170.

wider strip, slipping it between the side batten and the butt piece which may then be tacked together.

Before marking off the holes, it is advisable to scribe the edge of the template on to the next plate, and then take the template down in order to see that there is no buckle in the tin, as this sometimes happens, and if the mould is marked off it leads

to some trouble to put matters right. If there is a buckle it will be in the forward strip of tin, and will be due to the bends not being set to the correct taper in the bottom before tacking up; when this happens the forward tin must be loosened from the side moulds without allowing them to alter their positions; the tin must then be laid fair and free from buckles, and again securely tacked. The complete mould is now to be placed in position to the scribe marks on the next plate and marked off, the holes in the stern frame being stamped, and any allowances for landings must be noted on the mould for reversing before making off on the plate.

Remove the template and make a gauge for the butt end, one at the step, and one at the frame forward of the stern frame; this is usually sufficient, and they are made close up, then in the shop another set of gauges is to be made inside these for applying to the plate when bending. Before taking the gauges down from the stern, mark on them the positions of holes on each side; these will be transferred to the inner set of gauges, and will indicate exactly whether the plate is being bent properly or not.

Fig. 170 is an illustration of the plate marked off, showing a portion of the template removed, the lower part of the figure representing the template broken off along the keel batten, and showing portions of the tin strips. The centre of bend is marked in for one side, and the shaded portion of the upper part represents the size of a plate (an old one will do) which is to be made off the shoe plate in the flat, one for each half, and is to be bolted securely to the inside of the shoe plate after bending up as much as the punching machine will allow in the manner shown in fig. 165; this extra plate will be kept short of the bending line the thickness of the shoe plate, and when setting to shape at the furnace it will so stiffen the sides that in squeezing together in an inverted position on the slab, as shown in fig. 171, all the bending effect will be thrown on the corners and the keel part, but as the plate is inverted on the slab the bend may be kept out of the keel part by the use of the flatter. Assuming the plate has been bent as

much as possible in the punching machine, it should be taken to the slab, and stood in an inverted position with the edges resting in the bosom of angle bars; place pins against one bar, and the plate being hot, use a squeezer, or what is sometimes called a wheeze, against the other bar till the plate is closed sufficiently. In the case of very heavy plates it is sometimes necessary to use

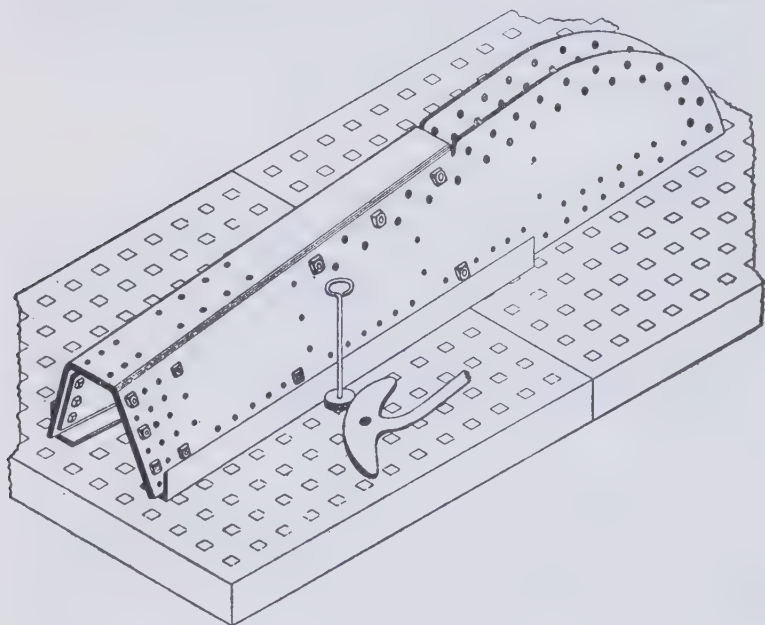


Fig. 171.

a screw jack in place of a wheeze, but, of course, in the more advanced shipyards the portable hydraulic ram would be brought into use. The method above described will be found particularly useful in shops not provided with a double roll flanging machine, and especially in repair yards where the facilities are not always what they might be.

PROBLEM 97.

To mark off an outside bilge plate.

Another instance of working to the centre of the thickness of plate is shown in fig. 172, in the templating of a bilge plate, and

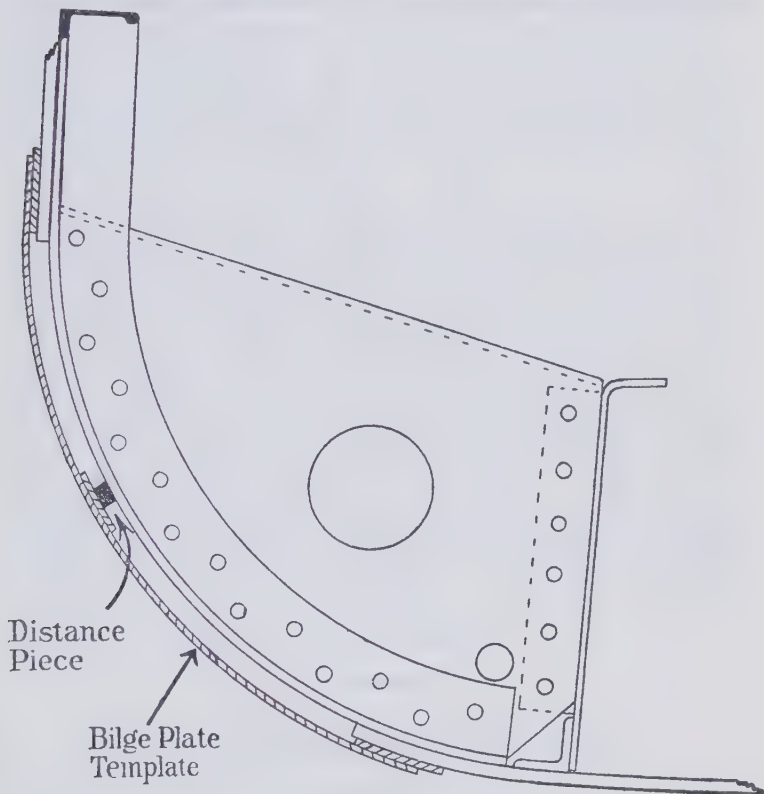


Fig. 172.

it is somewhat surprising to find so many who make no allowance for the thickness in such a job, but simply clip the template direct to the frames, altogether disregarding the fact that the liners have to be fitted between the plate and the frames, and when the plate is put in place it proves to be too narrow, and the holes in the

seams are far from fair. Make the template in the ordinary way, having the frame battens outside the seam battens; this may be done on the flat by measurement; then clip it to the top seam, and bend the mould till the bottom seam batten is in position, the template taking a natural bend and the frame battens held off from the frames by means of a fore and aft distance piece the same thickness as the liners; this distance piece may be tacked to the template before it is put in place, or a number of separate pieces may be used, one for each frame, the object being to have the centre of thickness, or neutral line of the frame battens in the same position as the neutral line of the plate.

As a general practice it will be found best to make shell moulds on the flat, then when they are put in position for marking, any buckle there may be in the mould will be in the plate when it is in its place; this will be particularly noticed in plates at the forward and after parts of the bilge strakes where there is fore and aft set as well as frame set, and if they are not furnaced to set to shape the buckle will be in the seams when the plates are in position; this buckle is usually slightly heated in position and closed by bolts. If the template be made in place there will be no buckle shown until it is taken down, when there may be some considerable difficulty in marking off the plate, for the template will not lay flat.

PROBLEM 98.

To obtain the bevel of a frame from the boards.

In fig. 173 is shown an instrument used to take the bevel of frames from the boards, and it is usually constructed of wood, the part A being triangular with a step at the right angle so that it is in line with the centre of the pin; thus the vertical line through the pin, and the base on XY forms a right angle. The blade B has a slot of convenient length, and it also has a step which is in line with the centre of the pin. The pin is fitted with a butterfly nut for tightening up, thus holding the two parts

securely if it is desired to retain the bevel. The pitch of the frames is their spacing on the centre line of the ship, and the height of the pin above the heel of the instrument is to equal the pitch as shown in the figure, where the height of the pin above XY is equal to 1 above XY, XY representing the frames brought into the same plane. If it be desired to find the bevel of frame No. 2 (they are here numbered from forward, but in shipbuilding they are numbered from aft), set the heel of A to the heel of frame No. 3', and extend the blade till the point is at 2', when X2'B will be the bevel required. It must be remembered to hold the instrument so that the bevel is taken at the shortest distance between the frames, and always set the heel to the frame next towards the amid-ship frame from the one of which the bevel is being taken.

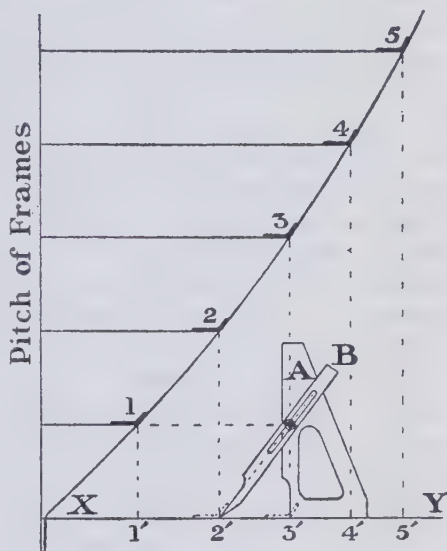


Fig. 173.

MASTS, YARDS AND BOOMS.

PROBLEM 99.

Though there appears to be a growing practice to make masts conical from the foot to the parallel portion at the deck and then conical to the top, the subject of the cambered mast still remains of sufficient importance to justify treatment in a work of this character, more especially in view of the fact that the cambered yard and boom is in no immediate danger of being displaced by

the conical or parallel, and there also remains a number of designers who favour the cambered mast as against the conical, particularly in regard to the masts of sailing ships. In the case of conical masts, etc., we think there will be no difficulty to the workman in ascertaining the various diameters at the butts, for he will only have to divide the difference between the diameters at the parallel portion and the ends by the number of spaces that occur in each, and add the amount to the end diameter, and to each one successively, to obtain the correct diameters for the length:—thus, supposing the diameter at the parallel portion to be 3ft. and the diameter at the end to be 1ft. 3in. and the number of spaces (which is one more than the number of butts) between is nine, the diameters will be 1' 3", 1' 5 $\frac{1}{3}$ ", 1' 7 $\frac{2}{3}$ ", 1' 10", 2' 0 $\frac{1}{3}$ ", 2' 2 $\frac{2}{3}$ ", 2' 5", 2' 7 $\frac{1}{3}$ ", 2' 9 $\frac{2}{3}$ ", 3' 0", all being taken as at the centre of thickness. With cambered masts the diameters cannot be worked out in this manner, and it is a tedious process to lay out a full length drawing to find them, for even by that method the curve will probably be more or less inaccurate unless the workman has an exceptionally good eye and very fine judgment as to curvature; and again, to take the diameters from a drawing by scale is not altogether satisfactory inasmuch that the mere thickness of a line when scaled up to full size will be enough to make a noticeable difference in the full curve of the camber. It is in order to overcome these difficulties, and to enable the workman to work to a full size drawing within a small compass, that we devised the method here described, basing it upon the assumption that the camber is always an elliptic curve. The matter of mountings, such as houndings, sling plates, etc., being put in in accordance with the drawing supplied, these do not call for any special treatment here; it is the duty of the workman to arrange them in accordance with the ideas of the designer, for we still believe a workman's duty is to do his work as directed.

To explain the method by which the mast plan system is developed, it will be necessary to show the means for obtaining an elliptic curve from a circle, and also the relation of circumferences

to concentric circles. We will deal first with the elliptic curve. Let it be required to find the curve or camber for a mast from the deck to the top, the camber from the deck to the foot being obtained in the same manner. Draw a line AB, fig. 174, of any convenient length, and from a point C on AB describe circles D and E equal to the top and deck diameters respectively. Through C draw XY at right angles to AB, cutting D in F, and E in G. Project F to E parallel to AB in *f*, and divide *Gf* into the same number of equal parts as there are to be *cambered* spaces, as shown by the divisions 1, 2, 3, 4, 5, 6, project these points to XY, which will indicate the various radii from which to draw the intermediate concentric circles representing a plan of the butt positions. As an illustration of the camber these circles produce, set off on AB the extent of the parallel portion from C in H, and from H set off along AB the number of cambered spaces as 1', 2', 3', 4', 5', 6', C', and at each point draw a line at right

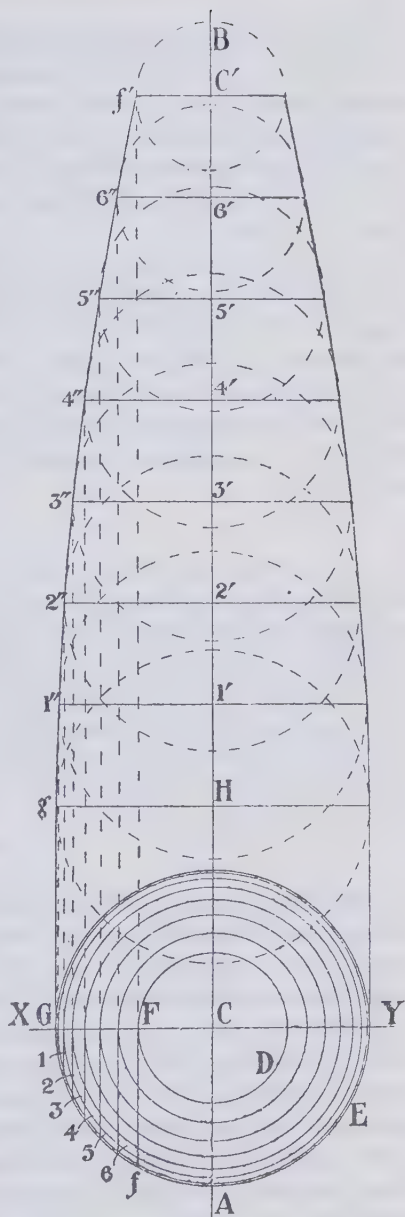
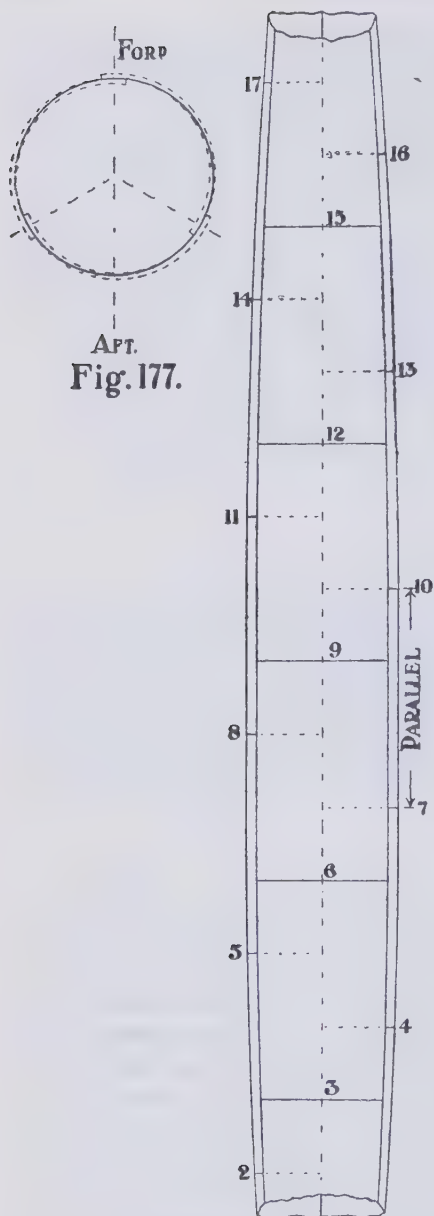


Fig. 174.

angles to AB; then project each point on GF by a line parallel to AB till it cuts its corresponding line in g , $1''$, $2''$, etc., to f' , through which draw the fair curve required. This curve will be elliptical, and may be taken as an elevation of the mast above the line XY, while the circles described about C may be regarded as a plan. It is not necessary for the purpose of this illustration that the divisions H, $1'$, $2'$, etc., on AB shall be equal to those into which the mast has to be divided so long as they are spaced alike from H, the resulting curve will still show a fair camber equally representative of the camber desired, and will make no difference to the plan about C, therefore one essential feature in the drawing of a mast is set out in the divisions between Gf on the circle E to represent the butts, and point G representing the whole of the parallel portion, and GF being equally representative of the camber gf' .

Instead of measuring the various diameters at the butts, and calculating the widths of plate, it will be found sufficient to calculate only the parallel portion, from which a diagram may be drawn to indicate all the intermediate diameters and widths, thus avoiding a considerable amount of calculating, and ensuring accuracy throughout the whole length. The plan already explained in fig. 174 shows the various radii from the point C to the points on CG projected from 1, 2, etc., on Gf, but we desire to set out the widths of plate as well.

From a point C on AB, fig. 175, with radii equal to that of the top and the parallel portion, measured at the centre of thickness, describe the circles D and E; from C draw CG at right angles to AB, cutting the circle D in F. From G draw GJ parallel to AB and set off GJ any length; join JC, then if a line be drawn from F parallel to AB till it meets JC in K, FK will be in the same proportion to GJ as the diameter and circumference of D are to those of E, and if GJ is set out to represent a given proportion of the circumference of E, such as a width of plate, FK will be in the same proportion, therefore it will only be necessary to set out the width of plate at the largest diameter along GJ to enable us to



two butt, and so on, for the remainder of the plates till the two short plates at the top are reached, when the numbers will increase; thus, No. 19 plate will extend from No. 16 butt to the top, No. 20 plate from No. 17 butt to the top, and No. 21 plate from No. 18 butt to the top. The diameter is to be taken as the mean indicated by the heavy circle in fig. 177, if it is expressed on the drawing in figures it will be this circle that is meant, and will represent the centre of the thickness of plate, but if the drawing distinctly states the diameter as inside, or outside, then the thickness must be added or deducted accordingly. We will take it the seams are to be double rivetted, and the butts to be spaced equally so that all plates except two at each end will be of the same length.

If the largest diameter of the mast is to be, say, three feet, a board four feet by two will be found large enough for our purpose

Figs. 176 and 177.

in marking out the plan. It will be found better to use a board than a plate for the drawing may then be made more neatly with blacklead. Having procured a suitable board, draw a line XY, fig. 178, near one edge, and at a point A near the centre erect a perpendicular AB. From A as centre describe the semi-circle CC equal to the largest diameter of the mast, the quadrant DE with radius equal to that of the foot, and the quadrant FG with radius equal to that of the top. Through B draw HJ parallel to XY, and from D and F draw lines intersecting the semi-circle in K and L. Divide the arc BK into the same number of equal parts as there are to be *cambered* spaces below the parallel portion, and the arc BL into the same number of equal parts as there are to be *cambered* spaces above the parallel portion, and through the points obtained draw lines parallel to XY. Set off from B along the line HJ the half-widths of plate at the parallel part taken at the centre of the seams, in M and N; join MA and NA, these lines will cut all the parallel lines in their respective widths of plate at the butts they represent, and also the foot and top widths. From M and N set off the position for the holes in the width of the seam, also the inside and outside landings and the first hole positions *aa* in the butt, and from these points draw lines *parallel* to MA and NA intersecting the lines drawn parallel to XY in a series of points which indicate the positions for the same holes on each butt represented; these are shown by heavy lines. The reason the lines are drawn parallel to MA and NA is because the seams will be the same width throughout the mast, the first hole from the inner landing on the foot line and top line being at *f*. Divide *aB* into as many parts as there are to be spaces between the holes in the butt, as *b, c, d, e*, and divide *fD* and *fF* into the same number of equal parts as *aB* in *g, h, j, k*; join *bg, ch, dj*, and *ek*, by lines intersecting the butt lines in corresponding butt hole positions. If the pitch of holes is too close in the butts approaching the ends, and it is desired to reduce the number of holes to equalise the pitch, it will be necessary to divide up the butt line on which the change is to be made and divide the top and foot lines accordingly, when the points may be joined to give the holes for the remaining butts, thus, supposing the pitch on butts numbered 3 and 16 have to be altered by the reduction of two holes, and all the butts from those towards the ends, allow the present

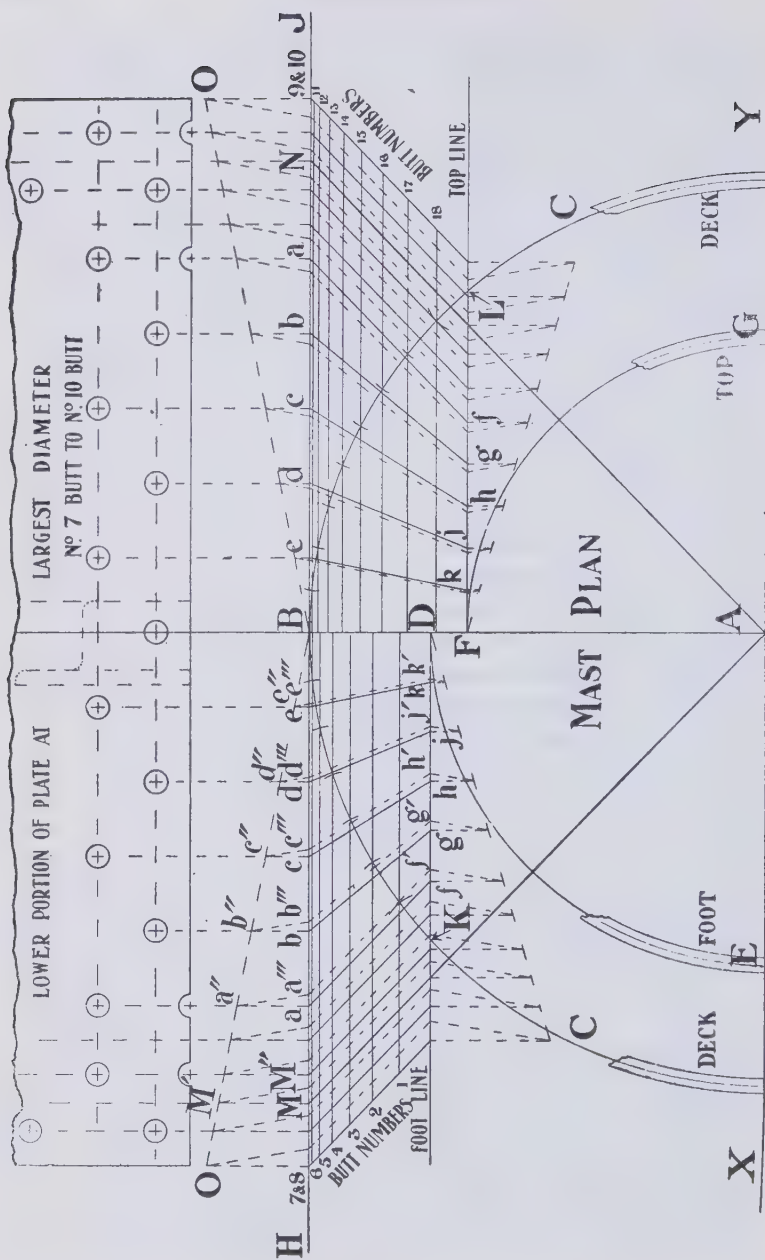


Fig. 178

divisions to terminate on butt lines 4 and 15 then divide 3 and 16 into the required number also the foot and top lines from *f* to D and *f* to F, and join them as before, when the positions for the holes on those butts in between will be indicated by the intersections.

Before dealing with the butt straps and doubling plates, it may be as well to mark out a plate from the plan so far as it has been drawn, the dotted lines not being taken into account. The first thing required is a seam template as shown in fig. 179. This should be of wood, about $\frac{3}{4}$ in. thick and the width of the seam from landing edge to landing edge, it should be quite straight, and it is best to have it planed in order that the marks may be more neatly drawn. Draw a straight line through the centre from end to end, and set off on one edge AB equal to the exact length of a full size plate from butt to butt, and cut the ends as shown having the ends at A and B exactly square with the centre line. Divide AB into three equal parts as at C and D, and at these points mark sight holes E and F on the centre line; these are to enable the workman to see when the template is bent correctly to the width lines during the marking off of a cambered plate, the positions C and D being where the intermediate butts occur. Draw the centre lines for the seam holes parallel to the centre line on the strip at the required spacing as G and H and where H crosses the butt divisions A, B, C, and D, mark holes as shown at 1, 2, 3, and 4. From A, B, and on each side of C set off 5, 6, 7, and

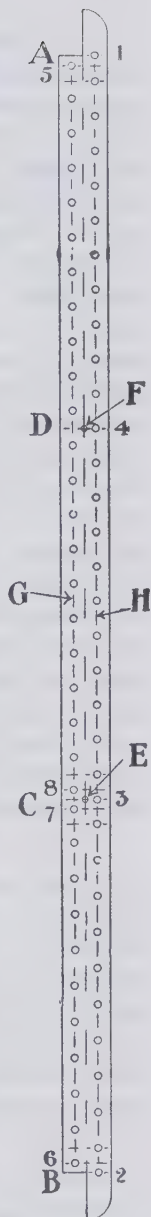


Fig. 179.

8 on G the position of the first hole from the butt edge of the plate, usually a little more than one and a half times the diameter of the hole, then divide the space 6 to 7 as nearly as possible to the required pitch, and divide 8 to 5 as nearly as possible to the required pitch, taking care to have a hole equally spaced on each side of D on G, the holes on H will be spaced intermediately to those on G. It may be observed the pitch from 6 to 7 will not necessarily be exactly the same as from 8 to 5, but the method of applying the strip will be found to make no difference to the accuracy of the work, as will be explained directly. The strip having been carefully marked off, get it bored to the size holes required, the sight holes need not be the same size, but it will make no difference if they are, the only advantage in having them smaller is that it may avoid them being marked as rivet holes. The holes being bored very clean, the strip should now be tested for accuracy by marking off on a plate the holes from A to C, then turn ends with the strip and over, and if it be then applied to the same marks they should be fair. Test it in the same manner from C to B, and if not satisfied that the holes are fair, the strip has not been accurately divided up and another should be made, for a little extra trouble in the beginning is far better than considerable trouble when assembling the plates, to say nothing of the drifting or reamering that may be needed before the work can be rivetted, which is at all times objectionable to a man who prides himself on the quality of his work.

Assuming the template strip to have been tested and proved satisfactory, we will proceed to mark off a plate, the most convenient as the first example being the parallel plate at the deck from number 7 butt to number 10 butt; the number of the plate will be 10, and as the widths of all the plates at the butt positions, and also the holes for the butts, are marked in the plan, fig. 178, we are enabled to work directly from the pile of plates without regard to which is uppermost.

Through the middle of the plate strike the line AB, fig. 180, and to it apply the centre line of template strip; mark the sight

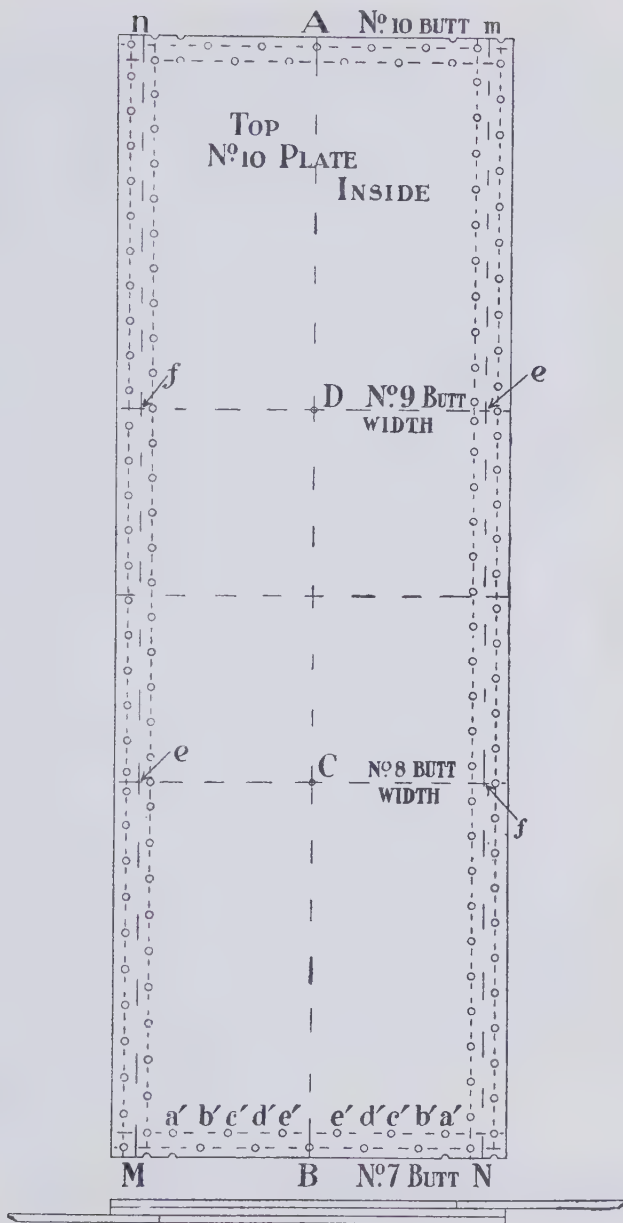


Fig. 180

holes C and D, and also scribe the dead lengths at A and B. At A, B, C, and D draw lines at right-angles to AB; this may be done with a Tee-square, and will indicate the positions of numbers 7, 8, 9, and 10 butts. From B set off BM and BN equal to BM and BN in fig. 178, and as the plate is to be parallel, the same distances are to be set off from A in *m* and *n*; join Mn and Nm, which will be the centre lines for the seams. Apply the strip so that its centre line is fair with Mn, and the sight holes E and F fair to the intersections at *e* and *f*; mark all the rivet holes. This done, turn ends with the template and turn it over, and apply it to Nm with the sight holes fair to *e* and *f*; mark the rivet holes. Strike the centre lines for the butt holes through the first two full holes at each end of the seams, then with a thin lath of about an inch in width, and nicely squared at one end, take off from the mast plan fig. 178, all the holes from B to *a*. They need only be taken from one side of the plan, either towards M or towards N, but the square end of the lath must be set fair to the centre line AB through the plan. Having taken off the positions for the butt holes on the lath, apply it to the plate, fig. 180, setting the square end fair to the centre line AB, and copy the marks for the butt holes on to the hole lines as at *e'*, *d'*, *c'*, *b'*, *a'* on each side of the centre; at the positions for *a'* there will also be half holes on the butt line as shown. If desired the full width of the plate may be set off from the plan—in fact, it would be best to do so, for it would ensure having the landing edge exactly correct throughout. These being lined in, the seams will now only need to be marked as to which side to punch and shear to complete the marking off. We will take it the plate is marked as representing the inside surface and the edge Mn to be outside, then the landing of Mn will require to be sheared from the opposite side of the plate, while the edge of Nm will be sheared from the surface shown, the holes along Nm being reversed for punching. The butts are usually sheared from the inside whether they have to be planed or not; if they are not to be planed they are mostly hammered up square before assembling, but of course it makes for better work if they are planed. Number 10 butt will be marked off from the same strip marks as number 7 butt, as the plate under consideration is the parallel plate.

We will now deal with the cambered plate, showing how the mast plan is used for that purpose. We will take plate number 13 as the example, that is from number 10 butt to number 13 butt, and the right hand portion of the mast plan being used to find all particulars. It will not be necessary to show a separate figure for this, as the explanation may easily be followed in fig. 180. Strike a centre line AB, fig. 180, and to it apply the seam template, marking the dead length at A and B, and also the sight holes at C and D. Through A, B, C, and D draw lines at right angles to AB, and set off from B a distance on each side equal to BN, fig. 178, then taking each butt line length from AB in the mast plan to where they are cut by NA, set them off for C, D, and A in fig. 180, that is, butt line length of number 11 butt taken from the mast plan is to be set off from C, number 12 from D, and number 13 from A, and at each point draw a short line sufficient to clearly indicate the widths of plate at these points, then apply the seam template to the width marks so that the sight holes are exactly over them, bending the strip edgewise for this purpose and bringing the end at number 13 butt correct to the square line through A; this will show the length at B slightly short, and will indicate the amount of "round up" required for the butt at the wide end. It will be very little, seldom more than an eighth of an inch, but still enough to take into account. These two points and the centre lengths are points through which to draw a fair curve, the narrow end being kept straight to avoid hollow shearing. After lining in the holes for the butts, apply the butt hole lath to the mast plan, and take off the holes for number 10 butt and for number 13 butt in the same manner as explained for the parallel plate, the holes for number 13 butt being taken from number 13 butt line in the mast plan, and the square end of the lath being kept fair to AB. If there are to be holes along the centre of the plate for a stiffening angle, these should be marked in on the same side of the plate so that they may be punched from the side the butts are punched from.

When making the rolling gauges from the mast plan, the radius from the top will be from A to F less half the thickness of

plate, and similarly to each point on AB where the butt lines meet AB, those for the top portion being taken on the right side and those for the bottom from the left, always less half the thickness of plate for inside gauges.

The next thing to be considered is the butt straps, and we will now explain the use of the mast plan in obtaining the spacing for the holes for all the straps, whether inside or outside, and the same lines will serve for doubling plates inside and outside. To avoid confusion we will first deal with the inside straps; these will of course be shorter than the width of plate, and are usually fitted against one landing and overlapping the other, and the difference in the length of butt strap as compared with the plate width it has to cover is governed by the thickness of the material only, and in no way by the diameter of the circle, for a given difference in two diameters will always produce the same difference in the two circumferences no matter what diameters may be used; thus the difference between 12 inches diameter and 24 inches diameter is the same as the difference between 24 and 36, and likewise the differences in circumference will be the same, therefore we have to consider the thickness only. Sometimes the thickness of the straps have to be greater than the plates to which they are attached, and to find the difference in circumference it will be necessary to add together the two thicknesses and multiply the result by $3\frac{1}{2}$, for the full circumference, then if we divide this difference by twice the number of plates in the circle we have the amount the strap is to be shorter from its centre line to the centre of seam line at each end for setting out on the mast plan, in this manner: suppose the thickness of plate to be $\frac{3}{8}$ " and the thickness of the straps to be $\frac{1}{2}$ ", these added together equal $\frac{5}{8}$ ", then this multiplied by $3\frac{1}{2}$ equal $2\frac{3}{4}$ " or 22 eighths, which, divided by six equals a bare $\frac{1}{2}$ " as the difference between a half length of strap and a half width of plate. If we were making a mast with two plates in the circle we should divide the 22 eighths by four instead of six.

We will take it the amount is $\frac{1}{2}$ " as above calculated, and proceed to adapt the mast plan for the inside butt straps. Draw

BO, fig. 178, at any convenient angle, and from each point on BH draw a line to BO at right angles to BH (these lines need not be at right angles, but must in any case be parallel to each other, and it will be found most convenient to draw them at right angles by means of a set square), as M to M'. From M set off M" equal to the difference found by calculation, viz., $\frac{1}{2}$ ", join M'M", and from each point on BO draw a line parallel to M'M", producing a new series of points on BH, as *a* to *a''* and then to *a'''*, the new points on BH will indicate the hole positions for the inside straps all proportionally spaced in accordance with the total difference calculated. This re-division is an application of Problem 16, page 7. The amount of lap on the hole at the end of the strap is also set out in the same manner because it will be slightly reduced as compared with the plate. The hole positions and lap on the foot line from D is to be treated in a similar manner, producing the new points *f'*, *g'*, *h'*, *j'*, *k'*, then these are to be joined to the new points on BH when all the intermediate butt lines will be re-divided for butt straps, and they are shown by dotted lines. In the case of outside straps the distance from M must be set off towards H instead of towards B, and the above instructions then apply producing new points and lines which show the extensions to be made for all outside butt straps. The same divisions may be used for the doubling plates if they are of the same thickness as the straps, but if they are to be thicker or thinner the plan must be re-divided accordingly after calculating the difference as with the straps.

To mark off an inside strap, fig. 181, strike the lines for the centres of holes parallel to each other, and distant apart equal to the distances on the plate, then through them draw a line at right angles as *xy*. This line should be about half a seam width one side of the centre of length, then apply the butt lath to the mast plan, fig. 178, and set the square end fair to AB on the butt line the strap is for, and take off the positions of the butt holes, lap, seam holes, and landing edge as shown by the dotted lines *a'''*, *f'*, *b'''*, *g'*, etc., which, by the way, are parallel to *af*, *bg*, etc., respectively. Set the square end of the lath square to *xy* on the

strap, and mark the hole positions on their respective lines as shown in the figure to correspond with those marked on the plate, taking care to have the three holes on the centre line to meet the half holes

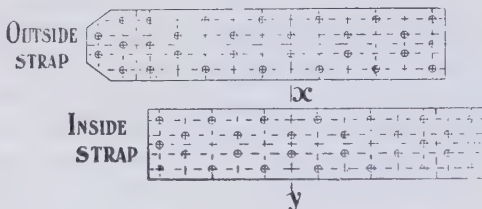


Fig. 181.

at the butts of plates ; the lap on the hole is to be marked at each end, and the seam holes will be at one end only. Line off the exact width of strap to complete the marking. Outside straps are marked off in a similar manner after the mast plan has been divided off for them.

In the case of overlap ends to plates in place of butts the same method will apply, the plan being at first drawn to represent the mean diameter of mast at the centre of thickness, then the re-divisions being set off inside and outside to account for the difference between the inside and outside laps, and in marking off a plate the extended width is to be taken for the outside lap end, the mean widths for the intermediate widths of plate, and the reduced width is to be taken for the inside lap end, and the camber produced by these points will be that to which to set the seam template, in which there are, of course, to be no half holes as with butts.

In assembling the mast, care must be taken that it is kept fair throughout its length, for unless it is properly supported it will tend to sag in the middle, or it may drop at the ends ; but it will assist materially if drifts be inserted in the butts, and full size bolts used in bolting together, the drifts being allowed to

remain in the plates till the rivetters take them out in the process of rivetting up. Any stiffening angles required inside may be marked off in the following manner: Use a number of battens about three inches wide, enough to template the entire length, then apply the first batten to the outside of the mast so that the holes are about three parts covered; then, with an ordinary marking peg, mark the holes on to the batten exactly over the holes in the mast, and before taking it off apply the second batten to the end of the first and number them both at their butts as No. 1, and proceed as with the first batten. Continue in this way for the whole length. When marking the holes on to the bars, the battens will have the marks the proper side up, and may be marked off direct; this will be found better than stamping the holes, for by that means of marking the marks have to be reversed on the battens before marking on to the bars, otherwise any holes in the plate that have not been punched quite on the line will be doubly inaccurate when the bars are put in position.

To mark in the rake for the foot of a mast.

When punching the foot plates for a mast it is well not to punch the seam holes within a foot or so of the lower ends. They may be centre-marked for convenience of knowing their positions if any of them are needed after the rake has been marked off, but as a rule the last few holes are marked during the process of marking out the rake, or what is mostly called the step. Bolt the bottom plates together in the manner shown in fig. 182, then by applying

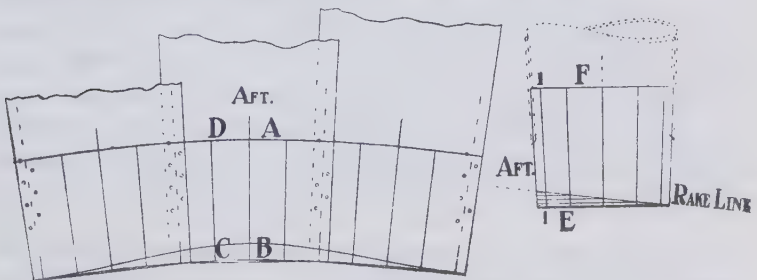


Fig. 182.

Problem 30, fig. 35, the arcs A and B may be drawn; these will be done with the angle template. Divide the arcs into twelve equal parts, four for each plate, and join them as at CD. Draw a full size view of the rake at the foot, the drawing to represent the centre of thickness as shown in the figure. Set off the base line and another at any convenient distance from it and parallel to it; divide these lines E and F proportionally for projection (Problem 39) and join the points obtained as at 1, 1, and continue the development as explained in Problem 54, page 77, taking care to have the shortest length of mast at the proper position on the plates in accordance with the drawings. In the case of marking the step in the bowsprit which has to be raked to the deck and also to set against a heel plate the rakes must be set out as shown in fig. 183, when the two rakes may be developed in the manner

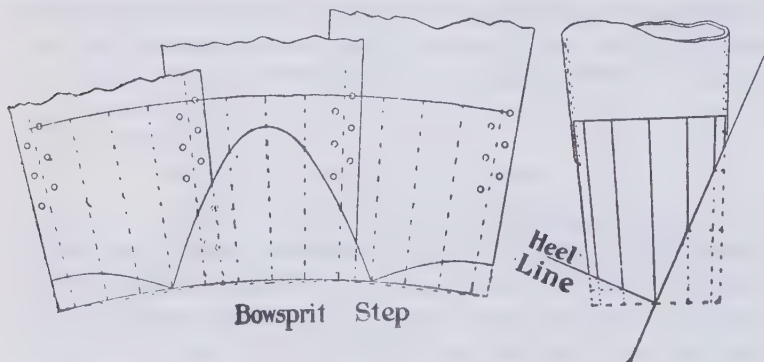


Fig. 183.

explained in Problem 54. It should be pointed out that the rakes of inside doubling plates will not be so great as the plate to which they are attached; on the other hand, the rake of an outside doubling will be greater. These differences will vary according to the angle of rake, and the full size figure must be set out in order to find the correct difference, but that having been found, the method of marking off will be the same as already explained.

By this system of marking off masts, booms, etc., it will be seen there is but one calculation to be made for circumference,

one division into widths of plates, one calculation for difference in respect to butt straps or inside and outside ends; no laying off of the whole length before marking any plates; any plate may be done direct from the pile, and the camber will be symmetrical throughout the entire length; while the space taken up by the drawing is reduced to a minimum and is wholly before the view of the workman at all times; and except for the details as to mountings the workman will have no need to make further reference to the drawing supplied from the office; and the result will be all that can be desired.

PROBLEM 100.

To mark off a hatch coaming.

In dealing with the hatch coaming, it will not be necessary to make much reference to the square cornered type, for each corner is marked off square to the foundation angle for the side plates, and square to a line across the ship for the end plates, but in the case of a round or radius corner the end plates are usually made to take the corner and extend a short distance along the sides where they are made to butt to the side plates, and in the process of marking off the templates, the beam rise has to be taken into account in order that the plates may stand properly vertical when finished. Before the hatch is done, the deck plates will be in position, and the foundation angle for the hatch will also be in place ready to receive the hatch plates. Before applying a template batten, strain a line fore and aft at the top edge of the foundation angle at the centre of the ship, and another line across the hatch at the top edge of the angle these lines should be strained quite taut, then where they cross measure their distance apart, which will be the amount of beam rise for the hatch. We will suppose the amount of beam rise across the hatch to be five inches, and the thickness of plate to be $\frac{1}{2}$ ". Obtain a batten wide enough to take the full depth of the main beam plus the

amount of beam rise; that is, if the beam is 10" deep, the batten should be 15" wide by $\frac{1}{2}$ " thick for the corners, it need not be of

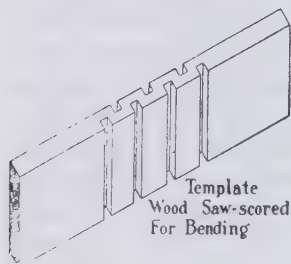


Fig. 184.

that thickness for the straight portion, and the reason it should be $\frac{1}{2}$ " thick is because that is to be the thickness of the plates, or in other words, the thickness of the corner battens should be the same as the thickness of plate. If battens cannot be obtained wide enough, use two half the width, and tack them together by cross strips clear of the corner.

Having secured the battens, score them as shown in fig. 184 to allow them to bend into the corner of the foundation angle, the saw-scoring being done on both sides will retain the neutral line of the batten in the same position as the neutral line of the plate. Strike a line along the batten

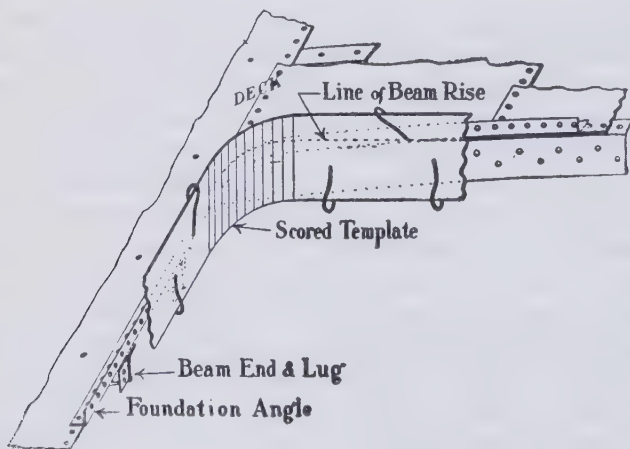


Fig. 185.

5" from one edge, that is, equal to the amount of beam rise (it is exaggerated here for the purpose of explanation), then set the edge fair to the top edge of the foundation angles at mid-ship, and the beam rise line fair to the top edge of the angle at the

side, the batten being pressed into the corner the while, and clipped, as shown in fig. 185, the batten will then be in a vertical position for the end and side plates. Mark off all the holes and scribe the edge of the main beam on to the batten for its curvature, and also the depth of the short beams at the sides. Note the positions for the butts of plates. In this way the whole hatch may be templated off at once, the beam rise line serving as the base from which to square off the upper portion of the coaming,

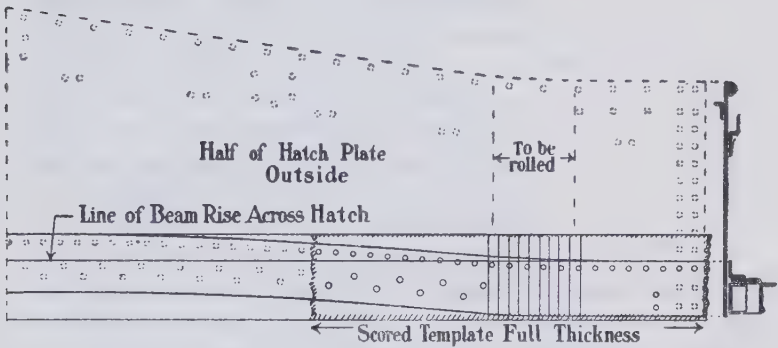


Fig. 186.

as in fig. 186, where a half plate is shown with all holes marked in for butt, moulding, ledge-iron, cleats, and fore-and-after rests. The moulding is usually solid, and should be bent on edge to the edge of the plate, before being bent to the radius of the corner. In this way the whole hatch may be completed in the shop before assembling on the ship, or if the foundation angle is not rivetted to the deck it may be removed after marking off the hatch templates, the hatch built to it, and the whole dropped into place complete.

PROBLEM 101.

Bending radius corners of angles.

Where the two flanges of an angle bar are of the same size and thickness, the amount of material required for a given radius may

be determined with fair accuracy by calculation, but when the flanges are not equal, it is not advisable to depend on calculating the length, but rather to ascertain the amount from the first bend, and even then much depends on the uniformity of the heat. Let us suppose a bar has to be bent for a hatch (radius corners).

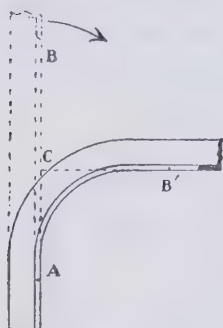


Fig. 187.

At the position for the first bend make two set marks A and B, fig. 187, a known distance apart, say 2' 6", then heat the bar as evenly as possible and bend it to the required radius, when B will be at B'; when cold, apply a square to the bend as at A, C, B', and measure the distance from A to C, and from C to B', add these together, and whatever difference there is between that and the first measurement AB will indicate the *draw* in bending the corner, and from that the remainder of the corners may be set off accordingly.

Care should be taken that the heat of each corner is the same as the first, for if the heat of either flange should be less than the other, the draw will not be the same as before, and there will consequently be a difference in the total length of bar.

PROBLEM 102.

To mould off from a damaged stem.

Before removing a damaged stem, a mould should be made in the form shown in fig. 188, in order that the correct shape of the bar may be secured when it is laid down after removal from its position in the ship, for without such a mould the template for the holes and the complete shape of the stem must be made from the ship, which is not so conveniently done as from the bar itself, and when the old stem is taken out, it will be found to have sprung considerably, then if a chain and screw be applied, it may be drawn to its original shape, and a complete mould made for all holes and the scarf, the holes in the damaged portion CD being

pitched off the same as the others for the new plates, but when the mould is made, marks should be put on it to correspond with

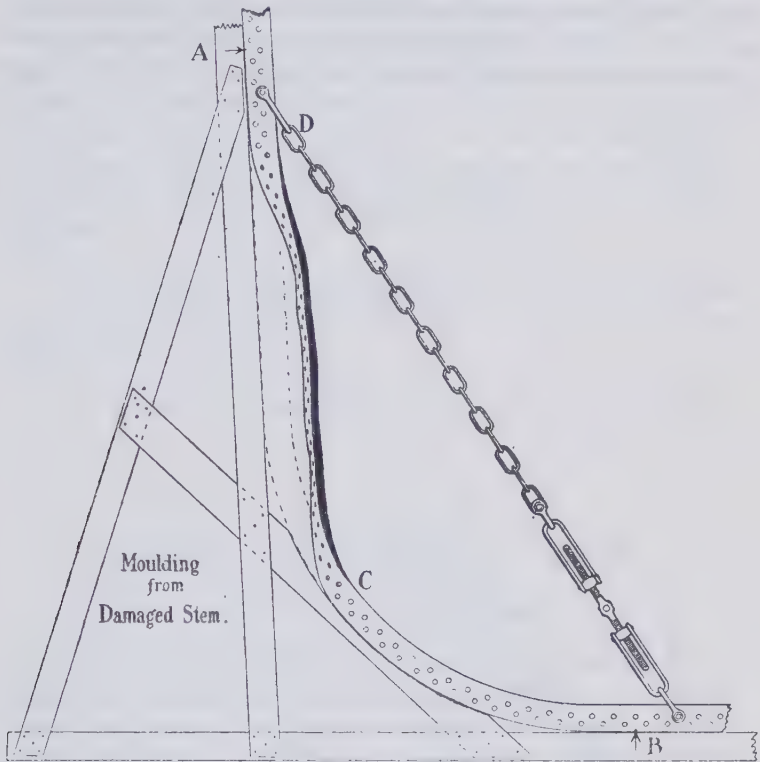


Fig. 188.

similar cut marks A and B on the stem, so that when it is drawn to shape on the ground, the mould will apply in the same position as when it was made, the touch marks being the guide.

PROBLEM 103.

To mark in the holes for a hawse-pipe.

The appearance of the hawse-pipe at the bow is invariably elliptical, but the pipe itself is cylindrical, the shape of the end

being produced by the angle at which it is set in the ship. It is usual to set them parallel to the centre line, but inclined from the bow plating to the deck, and the holes in these plates through which the pipe has to be fitted must not be marked out by any rough and ready method because the better the fit of the pipe

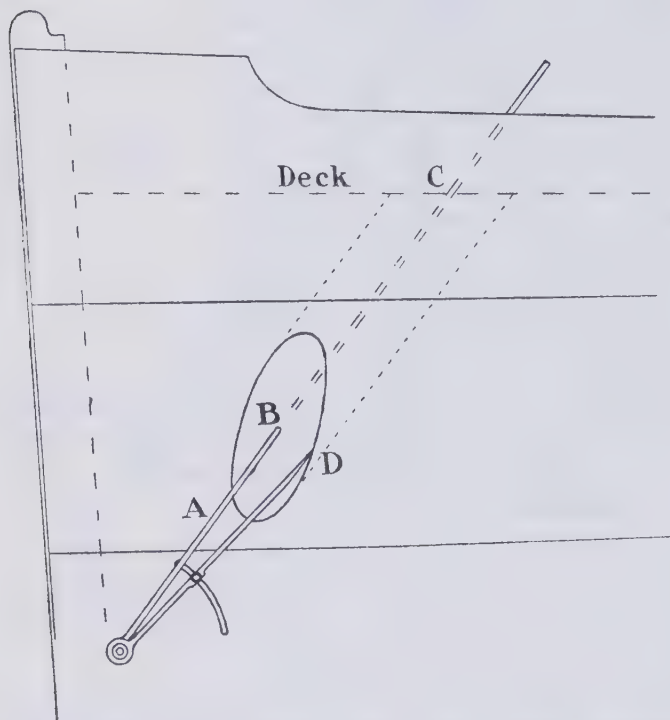


Fig. 189.

in these holes, the greater support it receives, and as they are cast very accurately to a cylindrical form, the holes in the plating should be marked out by a method which will be equally correct. What is required for this purpose is a compass, with one leg of great length, and to be made round, so that it may be revolved freely in a hole of suitable size, then the position of the pipe having been determined so far as deck and inclination are concerned, mark the position of the centre line on to the deck plate

and the bow plate, and at these positions drill holes slightly larger than the leg of the compass. To mark the hole in the bow, set the compass to the required radius, that is, equal to the outside radius of the pipe, and insert the long leg through the small holes as at B and C, fig. 189, BD being the radius. As the point D is made to trace the ellipse, the leg A will slide through the holes at B and C; the hole may then be cut or burnt out. The hole in the deck will be traced in the same manner with the compass inserted from the deck, the leg A being made to slide through the holes C and B.

The same result may be obtained by using a bent rod, one leg being kept straight and the other (the short one) being pointed to act as a scribe.

MISCELLANEOUS NOTES, RULES AND FORMULÆ.

(1) *To find the length of material for an external angle ring.*

Though a rule may be given by which to find the length for angle rings, so much depends on the heat at which the material is bent, the uniformity of the heat, and the time taken in turning the ring, that to give a definite rule which will meet all circumstances is practically impossible, for in two rings of equal size, there will generally be found a difference due to one or more of the above mentioned causes; thus the first may have been heated perfectly, and worked with good speed, whilst the second may have been badly heated, such as one flange hotter than the other, which may cause the workman to take more time in bending with the result that there will be a difference in the finished rings, but assuming all conditions to be favourable, and the two flanges to be the same size, the rule usually adopted is:—

Add to the inside diameter twice the thickness of iron measured through the root, and multiply the result by $3\frac{1}{2}$.

Example :—Required the length of iron for an external angle

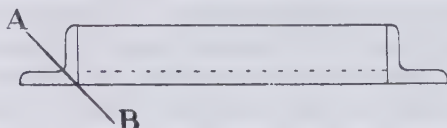


Fig. 190.

ring 2ft. inside diameter, the thickness through the root being $\frac{3}{4}$ in. as at AB, fig. 190.

Thickness $\frac{3}{4}$ in.

2

—

$1\frac{1}{2}$ in. plus 24in. dia. = $25\frac{1}{2}$ in. new dia.

$25\frac{1}{2}$ in. $\times 3\frac{1}{4}$ = $80\frac{1}{8}$ in. or 6ft. $8\frac{1}{8}$ in. length of iron.

This does not include any allowance for welding, but is the dead length of bar for a butt joint, and the extra for welding must be added according to the thickness of bar, usually the thickness is the amount to add, but if it is intended to weld up by laying a piece in, no extra need be added, the ends will only need to be jumped before scarfing. As the ends of angle bars are not affected much in the process of bending, a square cut end would produce a bad butt when the ring is bent, and to cut the ends to a bevel haphazard may still be unsatisfactory, the following method of ascertaining the required bevel for a given ring will be found useful. Strike a line AB, fig. 191, and set off AC equal to the inside radius



Fig. 191.

of the ring. Set off CD equal to the width of the stretching flange, and at right angles to AB; join AD and produce, then the angle CDE will be the bevel required, the length of bar to be measured along the root.

(2) *To find the length of material for an internal angle ring.*

RULE :—Deduct from the outside diameter twice the thickness of iron measured through the root, and multiply the result by $3\frac{1}{2}$.

Example :—Required the length of iron for an internal angle

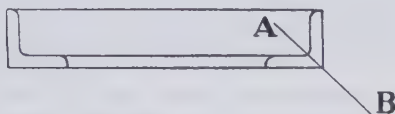


Fig. 192.

ring 2ft. outside diameter, the thickness through the root being $\frac{3}{4}$ in., as at AB, fig. 192.

Thickness $\frac{3}{4}$ in.

2

—

$1\frac{1}{2}$ in. deducted from 2ft. = $22\frac{1}{2}$ in. new dia.

$22\frac{1}{2}$ in. $\times 3\frac{1}{2}$ = $70\frac{3}{4}$ in. nearly, or 5ft. $10\frac{3}{4}$ in. length of iron.

The remarks on external rings apply also to internal rings, and in reference to the bevel for the inside flange, it will be found in the same manner except that it must be taken at CDA, fig. 191, instead of CDE, the length of bar being measured along the root as before.

(3) *To develop figures by means of rolling moulds.*

Sometimes figures of peculiar form have to be developed, and to lay them out by triangulation may be a tedious process, but if a mould be made to each end and securely connected, the ends being chamfered off to represent the centre of thickness, the mould may be rolled carefully so that it does not slip, when the correct development will be traced by the thin edge of the end moulds, and where they touch the plate at the same time points may be marked on the plate and joined for rolling lines.

(4) *Rolling conical plates.*

The process of rolling cones will be found to be greatly simplified, if the small end be kept close up against the standard of the rolls, the effect being to make the plate slip so that the large end gains all the time through the standard preventing the plate running through direct, as would be the case were it clear of the standard. When a cone is rolled up, it usually requires to be hammered to assume its correct shape, and when doing this the parts to be hammered on the outside will be where the plate does not touch the slab when stood up on end, owing to the rolling at that part being too quick. When the plate is fair to the slab all round, it will be set to its correct shape.

(5) *Rolling twisted shell plates for ships.*

A large number of plates at the fore and after ends of ships have to be twisted, and the twist is not regular through the length of plate on account of the gradually varying contour of the ships lines, the twist for one end of a plate being slightly different to that for the other end, but the practice is to ascertain the twist required about the middle and roll the plate till the ends are correct to the frame set, then the little inaccuracy of twist may be easily screwed out with the bolts when the plate is put in position, the frame set, being of more consequence, should be correct, for there is more difficulty in screwing a plate to frame set, than there is in drawing it to the proper twist. To find the line of twist, that is, the line which has to be fair to the rolls, apply a straight batten to three or four frames about the middle of the plate position, so that it is in the position nearest to a straight line, make a mark on the plate template where the straight-edge engages and, when marking off the plate, copy that rolling line on to the plate, then, when it is rolled up to the end gauges, the proper twist will be put in at the same time.

(6) *Taking particulars for short tapered liners with the two-foot rule.*

In taking the particulars for the tapered liners of clinker strakes, any number may be taken off with the aid of the two-

foot rule and a pocket book. The book should be ruled in column form for the numbers of the liners, their thickness, width, and then a larger space for the distances of the holes from the butt or thick end, each hole being measured from the end separately, and not from hole to hole. If the liners are to be of a uniform length, it only needs to be noted for the first one, and the same applies to the thickness. The following is an example of the method which we have found very useful, no battens being required, and, if necessary, the whole of the liners for a deck may be taken off in one visit.

No.	Thick- ness	Width	Butt end line	Holes pacings from butt			Length
1	$\frac{3}{8}$	$3\frac{1}{2}$		$3\frac{1}{4}$	$9\frac{1}{8}$	$14\frac{5}{8}$	18"
2	"	"		$3\frac{5}{8}$	$9\frac{1}{2}$	$15\frac{1}{8}$	"

An illustration of No. 1 liner is given in fig. 193.

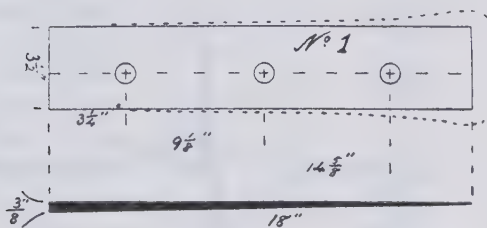


Fig. 193.

(7) *Joggling angle bars at the forge fire.*

If an angle bar be joggled on the anvil, a small projection will be made at the root of the standing flange which must be chipped off with the set, and to avoid this, as well as to establish the position of the joggle, a small portion is cut out of the root of

the bar in the manner illustrated in fig. 194, before joggling, it

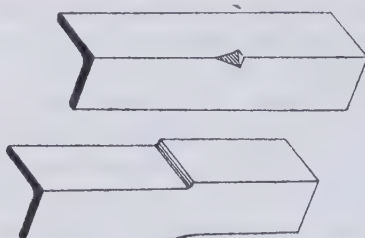
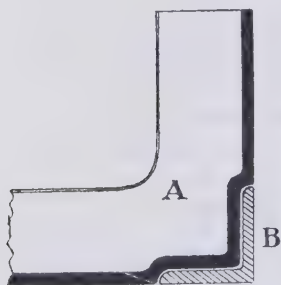


Fig. 194.

also serves to give the joggle a better shape than would be the case were the piece not cut out.

(8) *The double joggled angle corner.*

Formerly, angle bars were rolled with considerably more radius in the bosom of the bar than they are at the present time, and in turning a corner to an angle bar to fit within the bosom of another, more material is needed in proportion to the decrease of radius, or, as the corner is to be nearer square, so does the length of bar required become nearer a maximum, the greatest



length being for a dead square corner, when it will be equal to the added outside measurements after bending, less the thickness, but, as there is still a small radius to be considered, the amount to deduct from these added lengths will be a little more than once the thickness, and we find that to deduct once and a half is a very good rule for such work.

Figs. 195 and 196.

Let it be required to make an angle corner as shown in fig. 195, the bar A being joggled to fit within the bosom of B, and the outside surfaces to be level. From the added *inside* measurement of B deduct once and a half the thickness of A, the result will be the distance between the joggles C and D, fig. 196, thus :—If B measures $4" \times 4"$ outside, and is $\frac{1}{2}"$ thick, it will measure $3\frac{1}{2}" \times 3\frac{1}{2}"$ inside, these added together equal 7" from which is to be deducted once and a half the thickness of A, and if A is also $\frac{1}{2}"$ thick, there will be $\frac{3}{4}"$ to deduct from 7", leaving $6\frac{1}{4}"$ as the distance between C and D.

Where angle corners have to be mitred, the amount to be cut out will, of course, be a right angled piece for a right angled corner, as at EF, but when they have to be welded, there will be less cut out to allow for the welding as at GH. If the finished corner has to be other than square, say, an angle of 120 degrees, the amount to be cut out will be the difference between 120 degrees and 180 degrees, that is, the difference between the finished angle and a straight line.

Having cut and scarfed the bar, the standing flange must be set down with the fuller in the manner shown in fig. 197 before



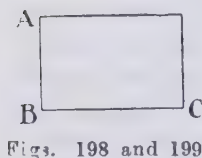
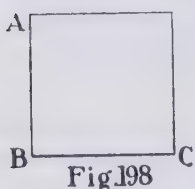
Fig. 197.

bending the corner, otherwise the flange will be drawn in, and will have to be fullered out, with the result that the material will be considerably reduced in thickness. Before welding up, the corner should be worked as near as possible to its finished shape, the scarf being brought level with the anvil on the inside, and if the bar is so long as to be likely to alter in carrying to and from the fire, it is well to bolt or clamp a stay across to keep it rigid.

(9) *To find the area of a square or rectangle.*

RULE:—Multiply together the lengths of two adjacent sides as AB and BC, figs. 198 and 199, the result will be in square measure.

In this, it is well to know duo-decimals, or what is often called cross-multiplication, and saves reducing the feet to



inches, where the sizes are given in feet and inches. It is worked by twelves instead of tens, there being twelve inches to the foot. Thus, suppose we desire to multiply 6ft. 7in. by 3ft. 5in., we place the 3ft. 5in. directly beneath the 6ft. 7in. and multiply first by the 3, as follows:— 3 times 7in. are 21 inches, or one 12 and 9 over; put down the 9, and carry 1 for the 12; now multiply the 6ft. by 3, which equals 18ft., to which add the 1 to be carried, making 19ft., the result so far will be 19ft. 9in. Now multiply by the 5 as follows:—

5 times 7 are 35, or two twelves and 11 over, place the 11 one space to the right of the 9 in the line beneath, and carry 2 for the twelves, then 5 times 6 are 30, to which add the 2 to be carried, making 32, which is two twelves and 8 over, place the 8 under the 9, and the 2 under the 19, and add together, the result will be in square measure. Thus:—

FT.	IN.		FT.	IN.
6	- 7	×	3	- 5
3	- 5			
<hr style="width: 100px; margin: 5px auto;"/>				
19	--9			
2	- 8	-	11	
<hr style="width: 100px; margin: 5px auto;"/>				

22 - 5 - 11, or $22\frac{1}{2}$ square feet nearly, it being

one square inch less than $22\frac{1}{2}$ square feet exact.

In adding together, after multiplying, the twelves have to be carried as before.

The same done in the usual way by reducing the feet to inches is as follows:—

FT.		IN.		FT.		IN.
6	—	7	×	3	—	5
12				12		
—				—		
79		×		41		
41						
—						
79						
3160						
—						
144	3,239	(22 square feet				
288						
—						
359						
288						
—						

71 square inches over.

Answer :— $22\frac{1}{2}$ square feet, less one square inch.

(10) *To find the area of a rhomboid.*

RULE :—Multiply one side by the perpendicular height from it.

Example :—Let AB, fig. 200, equal 2ft. 5in., and the perpendicular height CD equal 2ft. 1in. What is the area? By duo-decimals.

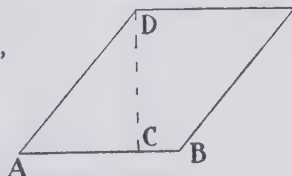


Fig. 200.

FT.		IN.		FT.		IN.
2	—	5	×	2	—	1
2	—	1				
—						
4	—	10				
		2	—	5		
—						
5	—	0	—	5	or 5 square feet, and 5 square inches	
—						

Usual Method.

FT.	IN.		FT.	IN.		
2	-	5	×	2	-	1
12				12		
29			×	52		
25						
145						
58						

144) 725(5 square feet.
 720

 5 square inches over.

Answer :—5 square feet and 5 square inches.

(11) *To find the area of a triangle.*

RULE :—Multiply the length of the base by half the perpendicular height from it.

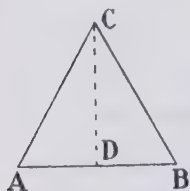


Fig. 201.

Example :—Required the area of a triangle A B C, fig. 201, the length of the base AB being 9ft. 8in., and half CD being 4 ft. 2in.

FT.	IN.		FT.	IN.		
9	-	8	×	4	-	2
4	-	2	×			
38	-	8				
1	-	7	-	4		
40	-	3	-	4	or 40 square feet and 40 square ins.	

By the usual method.

FT.	INS.		FT.	INS.		
9	-	8	×	4	-	2
12				12		
116			×	50		
50						

144) 5800 (40 square feet.
 576

 ..40 square inches.

Answer :—40 square feet and 40 square inches.

All triangles on the same base, and of the same vertical height are equal in area.

Example :—Let ABC, fig. 202, be a given triangle. Draw a line from B parallel to AC, then from any point D draw lines to A and C ; the triangle ADC will equal ABC in area.

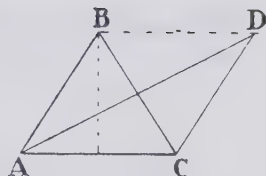


Fig. 202.

(12) To find the area of a regular polygon.

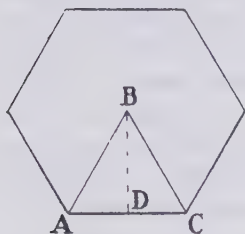


Fig. 203.

RULE :—Find the area of a triangle formed by one side and the centre, fig. 203, and multiply by the number of sides in the figure.

EXAMPLE :—Required the area of a regular hexagon, the length of side being 10 inches.

Find the radius of the circle which contains the figure by the standard for the number of sides on page 13, then the length of BD will be the square root of AB squared minus AD squared, and having found the length of BD, multiply AC by half of BD ; the result will be the area of one triangle, this multiplied by the number of triangles in the polygon will give the whole area.

10" length of side

1 standard number from page 13

10

10

100 = 10 squared.

25 = half the length of side squared.

75 = the difference ; then the square root of 75 will equal the length of BD.

8) 75 (8.66 inches as the length of BD, or say $8\frac{2}{3}$ ".

64

166) 1100

996

1726). 10400

10356

...44

$10" \times \text{half of } 8\frac{2}{3}" = 43\frac{1}{3}$ square inches, which, multiplied by the number of sides, equals

260 square inches the whole area.

(13) *To find the area of any irregular surface bounded by straight lines.*

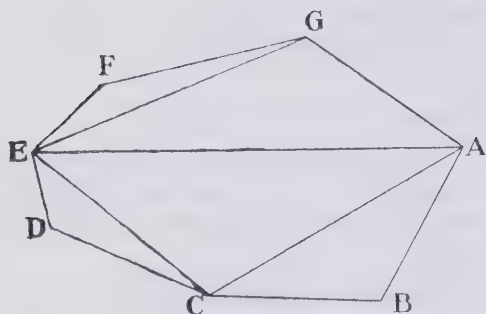


Fig. 204.

RULE :—Divide the figure up into any number of triangles, find their areas by Note No. 11 and add them together, the result will be the total area.

Example :—Required the area of an irregular seven-sided figure, fig. 204.

Let ABCDEFG be the figure; join alternate angles as AC, CE, EG, leaving a four-sided figure ACEG to be divided into two parts by AE, the figure will then be divided into five triangles. Find their areas by Note No. 11 and add them together.

Another Method.

Reduce the number of sides till the figure becomes a triangle of the same area, then find the area of the triangle by Note No. 11.

Example :—Required the area of the irregular five-sided figure ABCDE, fig. 205.

Join DA and draw EF parallel to DA. Produce BA in F; join DF. The figure has now been altered from five sides to four in FBCE.

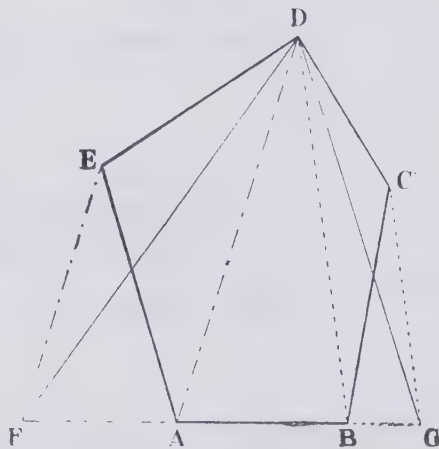


Fig. 205.

In the same manner join DB, and draw CG parallel to DB. Produce AB in G and join DG reducing FBCD to FGD, the area of which equals that of ABCDE and may then be determined by Note No. 11.

(14) *To find the area of a circle.*

RULE:—Square the diameter, and multiply the result by .7854.

Example:—Required the area of a circle, the diameter being 5ft. 4in.

FT.	IN.
5	4
12	
—	
64 inches in diameter.	
64	
—	
256	
384	
—	
4096 diameter squared.	
.7854 standard number.	
—	
1	6384
20	480
327	68
2867	2
—	
144(3216.9984 (22 square feet.	
288	
—	
336	
288	
—	
48 square inches	

Answer:—22 square feet and 48.9984square inches area).

(15) *To find the diameter of a circle from the area.*

RULE :—Divide the area by $\cdot 7854$ and find the square root, the result will be the diameter.

Example :—Required the diameter of a circle, the area being 38 square feet.

$$\begin{array}{r}
 \text{Standard number } \cdot 7854) 38 \cdot 0000 (48 \cdot 51 \\
 \underline{31 \ 416} \\
 6 \ 5840 \\
 \underline{6 \ 1832} \\
 40080 \\
 \underline{39270} \\
 810 \text{ remainder}
 \end{array}$$

$$\begin{array}{r}
 6) 48 \cdot 51 (6 \cdot 96 = \text{square root} \\
 \underline{36}
 \end{array}$$

$$\begin{array}{r}
 129) 1251 \\
 \underline{1161}
 \end{array}$$

$$\begin{array}{r}
 1386) 9000 \\
 \underline{8316}
 \end{array}$$

684 remainder.

Answer :—6·96 ft. dia.

To convert the decimal part of a foot into inches, multiply by twelve and mark off the same number of decimal places from the right as follows.

$$\begin{array}{r}
 \cdot 96 \text{ of a foot} \\
 \underline{12}
 \end{array}$$

11·52 inches or $11\frac{1}{2}$ in. full.

Therefore the answer to the last example is 6ft. $11\frac{1}{2}$ in. full.

(16) *To find the area of an ellipse, fig. 206.*

RULE:—Multiply the major and minor axes together and the result by .7854.

Example:—Required the area of an ellipse, the major axis AB being 12ft., and the minor axis CD 9ft.

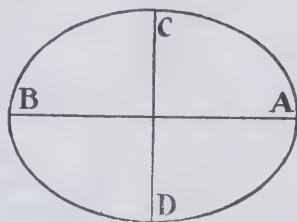


Fig. 206.

$$\begin{array}{r}
 12\text{ft.} \\
 9\text{ft.} \\
 \hline
 108 \times .7854 = \text{area.} \\
 \qquad \qquad \qquad .7854 \\
 \qquad \qquad \qquad 108 \\
 \hline
 \qquad \qquad \qquad 6\ 2832 \\
 \qquad \qquad \qquad 78\ 540 \\
 \hline
 \qquad \qquad \qquad 84.8232 \text{ square feet area.} \\
 \hline
 \hline
 \end{array}$$

To convert the decimal part of a square foot into square inches, multiply by 144 and mark off the same number of decimal places from the right as follows:—

$$\begin{array}{r}
 .8232 \text{ of a square foot} \\
 144 \\
 \hline
 3.2928 \\
 32.928 \\
 82.32 \\
 \hline
 118.5408 \text{ square inches, therefore the answer to the} \\
 \hline
 \hline
 \end{array}$$

last example is 84 square feet and $118\frac{1}{2}$ square inches full.

(17) *To find the slant area of a pyramid, fig. 207.*

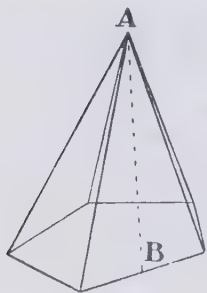


Fig. 207.

RULE:—Multiply the perimeter of the base by half the slant height.

Example:—Required the slant area of a pentagonal pyramid, the sides being 9in. at the base and 15in. centre of slant height, A.B.

9 in. width of side at the base.

5 number of sides.

—
45in. perimeter of base.

7.5in. half slant height.

—
225

315

—
337.5 square inches or 2 square feet and 49.5 square

inches.

(18) *To find the slant area of a frustum of a regular pyramid, fig. 208.*

RULE:—Add together the perimeters of the ends, and multiply by half the slant height.

Example:—Required the slant area of the frustum of a square pyramid, the sides being 13in. at the base, and 7in. at the top. the slant height AB being 18in.

13in. width of side at base

4 number of sides.

—
52in. perimeter of base.

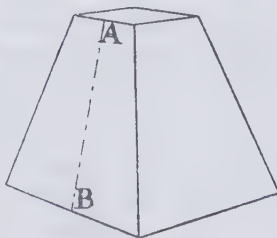


Fig. 208.

7in. width of side at top.

4 number of sides.

28in. perimeter of top.

52in.

28in.

80in. added perimeters.

9in. half slant height.

720 square inches slant area, or 5 square feet.

(19) *To find the slant area of a right cone*

RULE:—Multiply the circumference of the base by half the slant height.

Example:—Required the slant area of a right cone, the circumference of the base being 84in. and the slant height 26in.

84in. circumference of base.

13in. half slant height.

252

84

1092 square inches area, or 7 square feet and 84

square inches.

(20) *To find the slant area of a frustum of a right cone.*

RULE:—Add together the circumferences of the base and top, and multiply the result by half the slant height.

Example:—Required the slant area of the frustum of a right cone, the circumference of the base being 40in., top 28in., and half slant height 18in.

40in. circumference of base.

28in. „ „ top.

68in. circumferences added together.

18in. half slant height.

544

680

144)1224(8·5 square feet area.

1152

720

720

..

(21) *To find the convex area of a cylinder.*

RULE :—Multiply the circumference by the length.

Example :—Required the convex area of a cylinder, the diameter being 10ft. 7in., and the height 7ft.

FT.	IN.	
10	- 7	diameter.
12		
<hr/>		
127	inches	„
		3·1416 standard.
		127 inches.

21 9912
62 832
314 16

12)398·9832 inches circumference.

33·2486 ft. „
7 ft. height.

232·7402 square feet area.

(22) *To find the area of the surface of a sphere.*

RULE :—Square the diameter and multiply by 3·1416.

Example :—Required the area of a sphere, the diameter being 7ft.

7
7
<hr/>
49 dia. squared.

3·1416 standard.
49 dia. squared.

28 2744
125 664

153·9384 square feet area.

(23) *To find the convex area of a segment of a sphere when the diameter of the whole sphere is known, fig. 209.*

RULE:—Multiply the height of the segment by 3.1416, and the result by the diameter of the whole sphere, AB.

Example:—Required the convex area of a segment of a sphere, the height being 14ft, and the full diameter of the sphere 45ft.

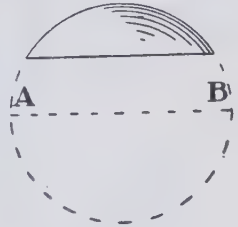


Fig. 209.

3.1416 standard.

14 ft. height.

12.5664

31.416

43.9824

45 ft. full diameter.

219.9120

1759.296

1979.2080 square feet convex area.

(24) *To find the convex area of a segment of a sphere when the diameter of the whole sphere is not known.*

RULE:—Add together the square of the height, and the square of half the diameter of the segment, then find the square root which will be the radius of a circle equal in area to the convex surface of the segment.

Example:—Required the convex area of the segment of a sphere, the height being 24in. and the diameter 64in.

24	32
24	32
—	—
96	64
48	96
—	—
576 height squared.	1024 half dia. squared.
1024	
576	
—	
4)1600(40in. square root=radius of circle to equal	
16	the area.
—	
80)..00	
..	
—	

To find the area of the circle see Note No. 14.

- (25) *To find the diameter of a circle which shall be equal in area to the added areas of a given number of smaller circles, such as the diameter of a Main Funnel to suit a given number of Boiler Tubes.*

RULE :—Multiply the square root of the number of small circles by their diameter.

Example :—Required the diameter of a Main Funnel to suit 576 Boiler tubes each 3in. internal diameter.

$$2)576(24 \times 3 \text{ in.} = 72\text{in. diameter.}$$

4

$$44)176$$

176

..

*Answer :—*6ft. diameter.

(26) *To find the solid content of a cube, capacity of a rectangular tank, or parallelopiped fig. 210.*

RULE :—Multiply together the length, breadth, and depth, as AB by BC, and the result by CD.

Example :—Required the solid content or capacity of a tank, the dimensions being, length 12ft., breadth 7ft., and depth 9ft. 6in.

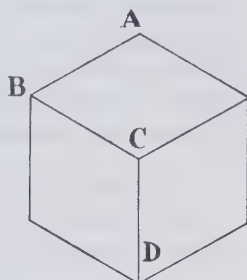


Fig. 210.

7 ft.

12 ft.

—
84 square feet product of length and breadth.

84

9·5 depth

—
42·0

756·0

—
798·0 cubic feet capacity.
—

As there are $6\frac{1}{4}$ gallons to the cubic foot, the capacity of the tank in the above example will be 798 multiplied by $6\frac{1}{4}$ which equals 4,987 $\frac{1}{2}$ gallons.

Fresh water being 10lbs. to the gallon, the weight of water in such a tank would be 4987·5 multiplied by 10 which equals 49,875 pounds or 22 tons, 3 cwt. 2 qrs. 3 lbs., but if the weight is to be found for salt water the number of gallons must be multiplied by 10·24 or the number of cubic feet may be multiplied by 64, that being the weight in pounds of a cubic foot of salt water.

(27) *Waterpressure in tanks.*

The pressure exerted by a column of water is approximately half a pound for every foot of height, the volume not affecting

the question of pressure in any way, for instance, the pressure against a dock gate is precisely the same per square inch as that exerted on the air pipe of a diver at the same depth, and if a tank 12ft. deep be filled with water the pressure against the bottom will be approximately 6 lbs. per square inch, the position of mean pressure being usually taken as one-third the height, and it is at this part the stays are generally placed.

It is quite a common practice to test ships ballast tanks by the column of water, the tank being filled and the water allowed to rise in a tube to the required height to give the pressure; thus if a ship floats on 9ft. light draught with her ballast tanks filled, and the depth of the tanks is 3ft. 6in. the water must be allowed to ascend the tube at least 5ft. 6in. in order to exert the required pressure, but it is usual to give about one foot more than that, the tube need not be very large, sometimes one is used about an inch diameter and screwed into a tank cover, holes being bored in the tube at suitable distances apart for the insertion of small plugs, the water being allowed to escape at that hole which is at the same level as the sea water were the ship afloat.

(28) *To find the third size for a tank to contain a given number of gallons when two sizes only are given.*

RULE :—Divide the number of gallons the tank has to contain by $6\frac{1}{4}$, and the result by the product of the two sizes given.

Example :—Required the third size for a tank to contain 3,000 gallons when the two sizes given are 6ft. and 8ft.

Gallons per cubic foot.	Gallons given.	
	6.25)3000.00(480 cubic feet	
	2500	
	—	
	5000	
	5000	
	—	
	...0	Sizes given
		6ft. \times 8ft. = 48ft.

$480 \div 48 = 10\text{ft.}$ the third size.

Fresh water is said to be at its minimum volume at 38 degrees Fahrenheit, above and below that degree it expands, therefore should a workman be testing a boiler with cold water he should run off a quantity after he has finished testing, for if he should be leaving the boiler filled with water during cold weather it is quite possible that the expansion due to the reduced heat of the water will burst the boiler, or at any rate so strain it as to make it unsafe. This precaution is particularly necessary in winter.

In the making of tanks with angle bars at the corners instead of flanging, it is usual to make two end frames and four connecting bars, the connecting bars to be thinned to take the standing flange of the end frames, and if the corners of the frames are not properly shaped the connecting bars will project beyond the level surface and will not look well in the finished tank. To avoid this the welded corners should be shaped as shown in fig. fig. 211, then the thinned flanges of the connecting bars will bring a level surface to the outsides of the bars and the plates.

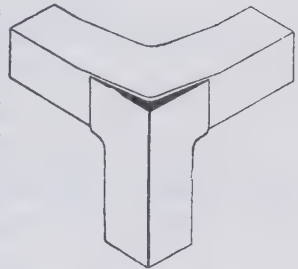


Fig. 211.

(29) *To find the solid content of a right cone.*

RULE :—Multiply the area of the base by the perpendicular height and divide the result by 3.

Example :—Required the solid content of a right cone, the area of the base being 113 square inches, and the perpendicular height 12in.

$$\begin{array}{r}
 113 \\
 12 \\
 \hline
 3)1356 \\
 \hline
 452 \text{ cubic inches.} \\
 \hline
 \hline
 \end{array}$$

The same rule applies for any regular pyramid.

Example :—Required the solid content of a square pyramid, the base being 4ft. square and the perpendicular height 6ft.

$$\begin{array}{r}
 4 \\
 4 \\
 \hline
 16 \text{ square feet area of base} \\
 6 \text{ perpendicular height} \\
 \hline
 3) 96 \\
 \hline
 32 \text{ cubic feet solidity.} \\
 \hline
 \hline
 \end{array}$$

(30) *To find the solid content of the frustum of a right cone, or regular pyramid.*

RULE :—To the added areas of the ends add the square root of their product, and multiply the result by one third of the height.

Example :—Required the solid content of the frustum of a right cone, the diameter of the base being 7ft., diameter of the top 5ft., and the height 4ft. 6in.

7ft. dia. of base.	5ft. dia. of top.
7ft.	5
<hr/>	<hr/>
49 „ squared.	25 „ squared.
·7854	·7854
<hr/>	<hr/>
196	100
245	125
3.92	2.00
34.3	17.5
<hr/>	<hr/>
38·4846 sq. ft. area of base.	19·6350 sq. ft. area of top.

$$38.4846 \times 19.635$$

$$19.635$$

$$.1924230$$

$$1.154538$$

$$23.09076$$

$$346.3614$$

$$384.846$$

$$2)755.6451210(27.489 \text{ square root of product of areas.}$$

$$4$$

$$47)355$$

$$329$$

38.4846 area of base

19.6350 area of top

$$544)2664$$

27.4890 square root of product.

$$2176$$

$$85.6086$$

$$5488)48851$$

1.5 one third of height.

$$43904$$

$$42.80430$$

$$54969)494721$$

$$85.6086$$

$$494721$$

$$128.41290 \text{ cubic feet.}$$

.....

To convert the decimal part of a cubic foot into cubic inches, multiply by 1728 and mark off the same number of decimal places from the right.

$$.4129$$

$$.1728$$

$$3.3032$$

$$8.258$$

$$289.03$$

$$412.9$$

$$713.4912 \text{ cubic inches}$$

The answer to the above example will therefore be 128 cubic feet and, 713.4912 cubic inches.

(31) *To find the solid content of a cylinder.*

RULE :—Square the diameter and multiply by .7854, and then by the height.

Example :—Required the solid content of a cylinder, the diameter being 10in. and the height 17in.

$$10 \times 10 = 100,$$

$$100 \times .7854 = 78.54.$$

$$\text{then } 78.54 \times 17 = \underline{\underline{1335.18}} \text{ cubic inches, answer.}$$

(32) *To find the solid content of a sphere.*

RULE :—Cube the diameter and multiply by .5236.

Example :—Required the solid content of a sphere, the diameter being 11ft.

$$\begin{array}{rcl}
 & 11\text{ft. dia.} & \\
 & 11 & \\
 \hline
 & 121 & \text{,, squared.} \\
 & 11 & \\
 \hline
 & .1331 & \text{,, cubed.} \\
 & .5326 & \\
 \hline
 & .7986 & \\
 & 3.993 & \\
 & 26.62 & \\
 & 665.5 & \\
 \hline
 & \underline{\underline{696.9116}} & \text{cubic feet solidity.}
 \end{array}$$

(33) *To find the solid content of a segment of a sphere.*

RULE :—Square the radius of the base, and multiply by 3 ; to this add the square of the height, then multiply the result by the height and by .5236.

Example:—Required the solidity of a segment of a sphere, the diameter of the base being 12ft. and the height 5ft.

$$\begin{array}{rcl}
 & 6\text{ft. radius of base} & \\
 & 6 & \\
 \hline
 & 36 & \text{,, ,, squared.} \\
 & 3 & \\
 \hline
 & 108 & \\
 & 25 \text{ height squared.} & \\
 \hline
 & 133 & \\
 & 5 \text{ height.} & \\
 \hline
 & 665 & \\
 & \cdot 5236 \text{ standard.} & \\
 \hline
 & \cdot 3990 & \\
 & 1.995 & \\
 & 13.30 & \\
 & 332.5 & \\
 \hline
 & 348.1940 \text{ cubic feet solidity.} & \\
 \hline
 \end{array}$$

(34) *To take particulars for ordering new furnaces for Scotch Boilers.*

So far as we are aware, the general practice in taking particulars for new furnaces for Scotch Boilers appears to be to first remove the old ones from a fair lap at the saddle end to the front, and then to have a mould made for each end an exact fit and marked for the bottom and the surfaces to face the new furnace. The moulds are then sent to the makers of the furnaces to be applied to the ends for the dead size. It is obvious that this process involves some delay in waiting for the new furnaces to be delivered, more especially if the makers are busy.

The method we have always adopted is to take the necessary particulars *before* the old furnaces are removed, sometimes the

sizes are taken the voyage before the repair is to be executed, and the new furnaces are then in hand waiting to be put in place for marking off as soon as the old ones are removed and the rivet holes drilled at the back ends.

Obtain a good steel measuring tape half an inch wide, and apply it to the inside of the front end at the back of the rivets after thoroughly cleaning off all scale; it will be found an easy matter for the tape supports itself when once it assumes close contact all round. Enter the circumference in a pocket-book. Take the circumference of the back end at the position the furnace has to be cut, and enter that in the book. Take the length over all, and make a note of the amount of flat surface required at each end. The thickness will now be required, and this may generally be obtained from the edge of the plate at the back end, it is not wise to take the thickness from the front edge on account of the thinning of the plate edge at that part in closing during the rivetting. Make a note of the thickness, and from that calculate the amount to be added to the *front* circumference only to give the outside measurement, the back end will already be the outside size. If the thickness is multiplied by six it will be sufficient, being but two sevenths of the thickness short in the full circumference. After taking the sizes as above, test the ends to see if they are round (often they are a little out), and make a note which direction is greater than the other and how much. These particulars will be all that are necessary for the makers of the various types of furnaces, and our experience is that they make them very exact, better even than to moulds. When placing furnaces in position to be marked off, always have the weld at the bottom, and before rivetting they should be well screwed up and closed all round, the bolting and closing being commenced at the bottom and worked up each side towards the top, and the rivetting commenced at the top and worked down one side to within about four or five rivets of the weld, then from the top down the other side till all the rivets are in; by this method of working there is the least risk of straining the weld.

Furnaces should, of course, be a good fit, and they are usually so accurately made as to require screwing into place for marking

off, and for this purpose screw bars of the design shown in fig. 212 will be found very convenient, the long hole at the end being made to receive a bolt passed through a rivet hole at the back lap of the furnace, one at each side; the front

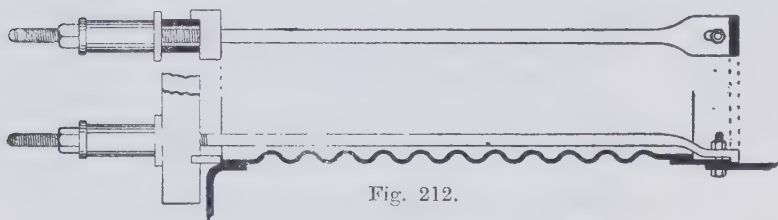


Fig. 212.

ends of the bars passing through a good cross bar, then as the side bars are screwed up the furnace is pushed into position. The bars should be about 2" diameter, and the back ends set with an easy joggle to clear the corrugations of the furnace, the lip on the end of the bars coming close against the landing edge of the old furnace. When withdrawing the new furnace the bolts are to be removed and the lips allowed to engage against the end of the furnace, a good shore or screw-jack being placed from one to the other to keep them in position; the front cross bar will be so placed that the screwing pressure is against the front of the boiler. In marking off it would be well to use a short nipple centre punch, as shown in fig. 213, with the barrel just an easy fit in the rivet hole, then there will be no fear of losing the marks in drawing the furnace out, also make a mark for a guide when placing the furnace in position after it is drilled.



Fig. 213.

(35) *To find the weight of square bar iron.*

The following rules for weights are based on a cubic foot weighing 480 lbs.

Rule for square iron:—Multiply the end area in square inches by the length in feet, and the result by $3\frac{1}{4}$.

Example :—Required the weight of a bar $3\frac{1}{2}$ in. square, and 16 ft. long.

$$\begin{array}{r}
 3.5 \\
 3.5 \\
 \hline
 1.75 \\
 10.5 \\
 \hline
 12.25 \text{ square inches area of end.} \\
 16 \text{ feet length.} \\
 \hline
 73.50 \\
 122.5 \\
 \hline
 196.00 \\
 3.33 \\
 \hline
 5.8800 \\
 58.800 \\
 588.00 \\
 \hline
 652.6800 \text{ pounds or 5 cwts. 3 qrs. } 8\frac{2}{3} \text{ lbs.}
 \end{array}$$

(36) *To find the weight of round bar iron.*

RULE :—Square the diameter in inches, and multiply by the length in feet, and the result by 2.62 for pounds weight.

Example :—Required the weight of a bar of round iron 6 in. dia. and 15 ft. long.

$$\begin{array}{r}
 6 \\
 6 \\
 \hline
 36 \text{ dia. squared.} \\
 15 \text{ length in feet.} \\
 \hline
 180 \\
 36 \\
 \hline
 540 \\
 2.62 \\
 \hline
 10.80 \\
 324.0 \\
 1080 \\
 \hline
 1414.80 \text{ pounds or 12 cwts. 2 qrs. } 14\frac{4}{5} \text{ lbs.}
 \end{array}$$

(37) *To find the weight of angle iron.*

RULE:—Add together the outside size of one flange and the inside size of the other, and multiply by the thickness and by $3\frac{1}{2}$ for the weight of one foot in length.

Example:—Required the weight of an angle bar 35ft. long measuring $6\frac{1}{2}$ in. by $4\frac{1}{2}$ in. outside sizes, by $\frac{1}{2}$ in. thickness.

$$6\frac{1}{2} \text{ plus } 4 = 10\frac{1}{2}$$

$$10\frac{1}{2} \times \frac{1}{2} = 5\frac{1}{4}$$

$$5\frac{1}{4} \times 3\frac{1}{2} = 17\frac{1}{2} \text{ pounds weight per foot.}$$

$$17\frac{1}{2} \text{ lbs.} \times 35\text{ft.} = \underline{\underline{612\frac{1}{2} \text{ lbs. or 5 cwts. 1 qr. } 24\frac{1}{2} \text{ lbs.}}}$$

(38) *To find the weight of plates.*

(a) When the thickness is expressed in 16ths.

RULE:—Multiply the superficial area in square feet by $2\frac{1}{2}$ for every sixteenth of thickness, or by 5 for every eighth.

Example:—Required the weight of a plate 24ft. long by 5ft. wide, the thickness being $\frac{9}{16}$ ths.

$$24\text{ft.} \times 5\text{ft.} = 120 \text{ square feet.}$$

$$120 \times 9 \times 2\frac{1}{2} = \underline{\underline{2,700 \text{ lbs. or 1 ton 4 cwts. 0 qrs. 12 lbs.}}}$$

(b) When the thickness is expressed in 20ths.

RULE:—Multiply the superficial area in square feet by 2 for every twentieth of thickness.

Example:—Required the weight of a plate 24ft. long by 5ft. wide the thickness being $\frac{9}{20}$ ths.

$$24\text{ft.} \times 5\text{ft.} = 120 \text{ square feet area.}$$

$$120 \times 9 \times 2 = \underline{\underline{2,160 \text{ lbs., or 19 cwts. 1qr. 4 lbs.}}}$$

(39) *To ascertain the amount due for a quarter-day or half-day at a given rate per week.*

RULE:—Call the shillings per week half pence; the result will be the amount for a quarter day. Call them pence, and it will be the amount for a half-day.

Example:—Required the amount due for a quarter-day at 33s. per week.

$$33 \text{ half pence equals } 1\text{s. } 4\frac{1}{2}\text{d. per quarter-day}$$

$$33 \text{ pence equals } 2\text{s. } 9\text{d. per half-day.}$$

(40) *To ascertain the value of a number of rivets at a given price per hundred.*

RULE:—Multiply the given number of rivets by the price per 100 expressed in shillings and decimal parts, and in the answer remove the decimal point two places to the left.

Example:—Required the value of 93 rivets at 12s. 6d. per hundred.

93 rivets
12·5 price per 100

465

186

93

1162·5 or after moving the decimal point 11·625 shillings. To convert the decimal part of 1s. to pence multiply by 12 as follows:—

·625

12

7·500 pence or $7\frac{1}{2}$ d.

Answer: 11s. $7\frac{1}{2}$ d.

Another example:—Required the value of 3,436 rivets at 17s. per 100.

3436

17

24052

3436

584·12 shillings or £29 4s. $1\frac{1}{2}$ d.

The above is of course simple proportion, the moving of the decimal point two places to the left being the same as dividing by 100.

TABLES

Fractions of an inch and their decimal equivalents.

Fractions.		Decimal Equivalents.	Fractions.		Decimal Equivalents.
$\frac{1}{64}$	..	·015625	$\frac{33}{64}$	..	·515625
$\frac{1}{32}$	..	·031250	$\frac{17}{32}$	..	·531250
$\frac{3}{64}$	..	·046875	$\frac{35}{64}$	..	·546875
$\frac{1}{16}$	..	·062500	$\frac{9}{16}$	..	·562500
$\frac{5}{64}$	..	·078125	$\frac{37}{64}$	..	·578125
$\frac{3}{32}$	..	·093750	$\frac{19}{32}$	..	·593750
$\frac{7}{64}$	..	·109375	$\frac{39}{64}$	..	·609375
$\frac{1}{8}$	..	·125000	$\frac{5}{8}$	..	·625000
$\frac{9}{64}$	..	·140625	$\frac{41}{64}$	..	·640625
$\frac{5}{32}$	..	·156250	$\frac{21}{32}$	..	·656250
$\frac{11}{64}$	..	·171875	$\frac{43}{64}$	..	·671875
$\frac{3}{16}$	..	·187500	$\frac{11}{16}$	..	·687500
$\frac{13}{64}$	..	·203125	$\frac{45}{64}$	..	·703125
$\frac{7}{32}$	..	·218750	$\frac{23}{32}$	..	·718750
$\frac{15}{64}$	..	·234375	$\frac{47}{64}$	..	·734375
$\frac{1}{4}$	..	·250000	$\frac{3}{4}$	..	·750000
$\frac{17}{64}$	..	·265625	$\frac{49}{64}$	..	·765625
$\frac{9}{32}$	..	·281250	$\frac{25}{32}$	..	·781250
$\frac{19}{64}$	..	·296875	$\frac{51}{64}$	..	·796875
$\frac{5}{16}$	..	·312500	$\frac{13}{16}$	..	·812500
$\frac{21}{64}$	..	·328125	$\frac{53}{64}$	..	·828125
$\frac{11}{32}$	..	·343750	$\frac{27}{32}$	..	·843750
$\frac{23}{64}$	..	·359375	$\frac{55}{64}$	..	·859375
$\frac{3}{8}$	..	·375000	$\frac{7}{8}$	..	·875000
$\frac{25}{64}$	..	·390625	$\frac{57}{64}$	..	·890625
$\frac{13}{32}$	..	·406250	$\frac{29}{32}$	..	·906250
$\frac{27}{64}$	..	·421875	$\frac{59}{64}$	..	·921875
$\frac{7}{16}$	..	·437500	$\frac{15}{16}$	..	·937500
$\frac{29}{64}$	..	·453125	$\frac{61}{64}$	..	·953125
$\frac{15}{32}$	..	·468750	$\frac{31}{32}$	..	·968750
$\frac{31}{64}$	..	·484375	$\frac{63}{64}$	..	·984375
$\frac{1}{2}$	..	·500000	1	..	1·000000

DIAMETERS AND THEIR CIRCUMFERENCES.

On pages 270 and 271 will be found two tables of diameters and their circumferences for every sixteenth of an inch diameter from $\frac{1}{16}$ in. to 144ft. $11\frac{1}{16}$ in., the circumferences being calculated to the nearest $\frac{1}{32}$ nd part of an inch.

TABLE A is arranged for inches and parts from $\frac{1}{16}$ in. dia. to $11\frac{1}{16}$ in. dia. in the following manner.

The TOP line contains diameters in parts of an inch, and their circumferences appear directly beneath in the second line.

The FIRST column contains diameters in even inches, and their circumferences appear directly opposite in the second column.

To find the circumference of a circle when the diameter is given in inches and parts, follow along the line opposite the inches till the column beneath the fraction is reached when the required circumference will be found in the space where the line and column cross.

Example :—Required the circumference of a circle, the diameter being $3\frac{7}{16}$ in.

Opposite 3in. and beneath $\frac{7}{16}$ in. will be found $10\frac{1}{8}$ in. the circumference required.

Example 2 :—Required the circumference of a circle, the diameter being $9\frac{3}{4}$ in.

Opposite 9in. and beneath $\frac{3}{4}$ in. will be found 2ft. $6\frac{1}{2}$ ins. the circumference required.

TABLE B is arranged for feet only. There are nine lines of diameters containing 16ft. in each line, thus giving a range of 144ft. in diameters rising in feet. The circumference for each diameter appears directly beneath the diameter in the intermediate lines. These are also calculated to the nearest $\frac{1}{32}$ in. circumference.

Example :—Required the circumference of a circle, the diameter being 17ft.

Directly beneath 17ft. in the second line of diameters will be found 53ft. $4\frac{7}{8}$ in. the circumference required.

Example 2:—Required the circumference of a circle, the diameter being 107ft.

Directly beneath 107ft. in the seventh line of diameters will be found 336ft. $1\frac{1}{8}$ in. the circumference required.

DIAMETERS IN FEET AND INCHES.

When the diameter is given in feet and inches, use both Tables A and B in the following manner. Find the circumference for the feet in Table B, and to it add the circumference for the inches from Table A. The result will be the required circumference.

Example:—Require the circumference of a circle, the diameter being 22ft. $5\frac{1}{4}$ in.

Directly beneath 22ft. in the second line of diameters in Table B will be found 69ft. $1\frac{3}{8}$ in. the circumference for the feet.

Opposite 5in. and beneath $\frac{1}{4}$ in. in Table A will be found 1ft. $4\frac{1}{2}$ in. the circumference for the inches. Then—

By Table B .. 22ft. 0 in. dia. = 69ft. $1\frac{3}{8}$ in. cir.

By Table A .. 0ft. $5\frac{1}{4}$ in. dia. = 1ft. $4\frac{1}{2}$ in. cir.

By combined Tables 22ft. $5\frac{1}{4}$ in. dia. = 70ft. $5\frac{7}{8}$ in. cir.

Example 2:—Required the circumference of a circle, the diameter being 109ft. $9\frac{5}{8}$ in.

Directly beneath 109ft. in the seventh line of diameters in Table B will be found 342ft. $5\frac{3}{8}$ in. the circumference for the feet.

Opposite 9in. and beneath $\frac{5}{8}$ in. in Table A will be found 2ft. $5\frac{1}{4}$ in. the circumference for the inches. Then these added will give the required circumference, thus:—

By Table B .. 109ft. 0 in. dia. = 342ft. $5\frac{3}{8}$ in. cir.

By Table A ... 0ft. $9\frac{5}{8}$ in. dia. = 2ft. $5\frac{1}{4}$ in. cir.

By combined Tables 109ft. $9\frac{5}{8}$ in. dia. = 344ft. $10\frac{7}{8}$ in. cir.

The circumference of circles of greater diameter than 144ft. may be found by taking the diameter in feet in two or more quantities, and adding the circumference for the inches in the ordinary way, thus :—

Required the circumference of a circle, the diameter being 374ft. $9\frac{3}{4}$ in.

$$\text{By Table B} \dots 144\text{ft. } 0 \text{ in. dia.} = 452\text{ft. } 4\frac{2}{3}\frac{1}{2}\text{in. cir.}$$

$$\text{By Table B} \dots 144\text{ft. } 0 \text{ in. dia.} = 452\text{ft. } 4\frac{2}{3}\frac{1}{2}\text{in. cir.}$$

$$\text{By Table B} \dots 86\text{ft. } 0 \text{ in. dia.} = 270\text{ft. } 2\frac{4}{3}\frac{1}{2}\text{in. cir.}$$

$$\text{By Table A} \dots 0\text{ft. } 9\frac{3}{4}\text{in. dia.} = 2\text{ft. } 6\frac{2}{3}\frac{0}{2}\text{in. cir.}$$

$$\text{By combined Tables} \quad \underline{\underline{374\text{ft. } 9\frac{3}{4}\text{in. dia.}}} = \underline{\underline{1177\text{ft. } 6\frac{1}{16}\text{in. cir.}}}$$

The same example worked out by the standard 3·14159 (the number used for compiling the tables) which is 100000th part nearer than 3·1416 is as follows :—

Diameter as given 374ft. - $9\frac{3}{4}$ in.

12

4497·75 = diameter reduced to inches

3·141 59 = standard

40479 75

2 24887 5

4 49775

179 9100

449 775

13493 25

12) 14130·0864225 inches cir.

1177ft. 6·0864225in. Answer.

In the Table of decimal equivalents for fractions of an inch on page 265 will be found ·062500 as the equivalent for $\frac{1}{16}$ in. and this

deducted from $\cdot0864225$ will show the amount of error in finding the circumference from the tables given.

$\cdot0864225$

$\cdot0625000$

$\cdot0239225$ of an inch too much by the tables, or less than $\frac{1}{8}\frac{1}{2}$ in.

TABLES A and B

may be obtained, mounted on linen and varnished, 23½ in. by 18 in., eyeletted in the four corners, suitable for hanging in the Workshop, the Office, or the Study

PRICE 1s. 6d. NET, POST FREE.

DIAMETERS

For every $\frac{1}{16}$ in. Diameter to 144 ft.

TABLE A.

[illegible]

CIRCUMFERENCES AND THEIR DIAMETERS.

On pages 274 and 275 will be found two tables of circumferences and their diameters for every eighth of an inch circumference from $\frac{1}{8}$ in. to 200ft. $11\frac{7}{8}$ in. the diameters being calculated to the nearest $\frac{1}{32}$ nd part of an inch.

TABLE C is arranged for inches and parts from $\frac{1}{8}$ in. cir. to $11\frac{7}{8}$ in. cir. in the following manner.

The TOP line contains circumferences in parts of an inch, and their diameters appear directly beneath in the second line.

The FIRST column contains circumferences in even inches, and their diameters appear directly opposite in the second column.

To find the diameter of a circle when the circumference is given in inches and parts, follow along the line opposite the inches till the column beneath the fraction is reached when the required diameter will be found in the space where the line and column cross.

Example :—Required the diameter of a circle, the circumference being $2\frac{3}{4}$ in.

Opposite 2 in. and beneath $\frac{3}{4}$ in. will be found $\frac{7}{8}$ in. the diameter required.

Example 2 :—Required the diameter of a circle, the circumference being $10\frac{1}{2}$ in.

Opposite 10 in. and beneath $\frac{1}{2}$ in. will be found $3\frac{1}{8}$ in. the diameter required.

TABLE D is arranged for feet only. There are 25 lines of circumferences on the two pages containing 8ft. in each line, thus giving a range of 200ft. in circumferences rising in feet. The diameter for each circumference appears directly beneath the circumference in the intermediate lines. These are also calculated to the nearest $\frac{1}{32}$ in. in diameter.

Example :—Required the diameter of a circle, the circumference being 29ft.

Directly beneath 29ft. in the fourth line of circumferences will be found 9ft. $2\frac{2}{3}$ in. the diameter required.

Example 2 :—Required the diameter of a circle, the circumference being 192ft.

Directly beneath 192ft. in the 24th line of circumferences will be found 61ft. 1 $\frac{3}{8}$ in. the diameter required.

CIRCUMFERENCES IN FEET AND INCHES.

When a circumference is given in feet and inches, use both Tables C and D in the following manner. Find the diameter for the feet in Table D, and to it add the diameter for the inches from Table C. The result will be the required diameter.

Example :—Required the diameter of a circle, the circumference being 18ft. 1 $\frac{3}{8}$ in.

Directly beneath 18ft. in the Third line of circumferences in Table D will be found 5ft. 8 $\frac{3}{4}$ in., the diameter for the feet.

Opposite 1in. and beneath $\frac{3}{8}$ in. in Table C will be found $\frac{1}{16}$ in., the diameter for the inches. These added together will give the required diameter, thus :—

By Table D ..	18ft. 0 in. cir.	=	5ft. 8 $\frac{3}{4}$ in. dia.
By Table C ..	0ft. 1 $\frac{3}{8}$ in. cir.	=	0ft. 0 $\frac{1}{16}$ in. dia.
By combined Tables	<u>18ft. 1$\frac{3}{8}$in. cir.</u>	=	<u>5ft. 9$\frac{1}{16}$in. dia.</u>

Example 2 :—Required the diameter of a circle, the circumference being 177ft. 7 $\frac{3}{8}$ in.

Directly beneath 177ft. in the 23rd line of circumferences in Table D will be found 56ft. 4 $\frac{3}{8}$ in. the diameter for the feet.

Opposite 7in. and beneath $\frac{3}{8}$ in. in Table C will be found 2 $\frac{1}{8}$ in., the diameter for the inches. These added together will give the diameter required, thus :—

By Table D ..	177ft. 0 in. cir.	=	56ft. 4 $\frac{3}{8}$ in. dia.
By Table C ..	0ft. 7 $\frac{3}{8}$ in. cir.	=	0ft. 2 $\frac{1}{8}$ in. dia.
By combined Tables	<u>177ft. 7$\frac{3}{8}$in. cir.</u>	=	<u>56ft. 6$\frac{1}{4}$in. dia.</u>

TABLES OF CIRCUMFERENCES
FOR EVERY $\frac{1}{8}$ IN. CIRCUMFERENCE
CALCULATED TO THE NEAREST

TABLE C (Inches and Parts).

	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Ft. in.	Circums.	0 0 $\frac{1}{8}$	0 0 $\frac{1}{4}$	0 0 $\frac{3}{8}$	0 0 $\frac{1}{2}$	0 0 $\frac{5}{8}$	0 0 $\frac{3}{4}$	0 0 $\frac{7}{8}$
Circumferences	Diameters	0 0 $\frac{3}{8}$	0 0 $\frac{1}{4}$	0 0 $\frac{1}{8}$	0 0 $\frac{1}{8}$	0 0 $\frac{1}{4}$	0 0 $\frac{1}{4}$	0 0 $\frac{3}{8}$
0 1	0 0 $\frac{1}{8}$	0 0 $\frac{1}{4}$	0 0 $\frac{1}{4}$	0 0 $\frac{1}{8}$	0 0 $\frac{1}{8}$	0 0 $\frac{1}{4}$	0 0 $\frac{1}{4}$	0 0 $\frac{3}{8}$
0 2	0 0 $\frac{1}{4}$	0 0 $\frac{1}{2}$	0 0 $\frac{1}{2}$	0 0 $\frac{1}{2}$	0 0 $\frac{1}{2}$	0 0 $\frac{3}{4}$	0 0 $\frac{3}{4}$	0 0 $\frac{3}{4}$
0 3	0 0 $\frac{3}{8}$	0 1	0 1 $\frac{1}{8}$	0 1 $\frac{1}{8}$	0 1 $\frac{1}{8}$	0 1 $\frac{1}{4}$	0 1 $\frac{1}{4}$	0 1 $\frac{1}{4}$
0 4	0 1 $\frac{1}{8}$	0 1 $\frac{1}{4}$	0 1 $\frac{1}{4}$	0 1 $\frac{1}{4}$	0 1 $\frac{1}{4}$	0 1 $\frac{1}{2}$	0 1 $\frac{1}{2}$	0 1 $\frac{1}{2}$
0 5	0 1 $\frac{1}{4}$	0 1 $\frac{1}{2}$	0 1 $\frac{3}{4}$	0 1 $\frac{3}{4}$	0 1 $\frac{3}{4}$	0 2	0 1 $\frac{3}{4}$	0 1 $\frac{3}{4}$
0 6	0 1 $\frac{3}{8}$	0 1 $\frac{3}{4}$	0 2	0 2 $\frac{1}{8}$	0 2 $\frac{1}{8}$	0 2 $\frac{1}{4}$	0 2 $\frac{1}{4}$	0 2 $\frac{1}{4}$
0 7	0 2 $\frac{1}{8}$	0 2 $\frac{1}{4}$	0 2 $\frac{1}{4}$	0 2 $\frac{1}{2}$	0 2 $\frac{1}{2}$	0 2 $\frac{3}{4}$	0 2 $\frac{3}{4}$	0 2 $\frac{3}{4}$
0 8	0 2 $\frac{1}{4}$	0 2 $\frac{1}{2}$	0 2 $\frac{1}{2}$	0 2 $\frac{3}{4}$	0 2 $\frac{3}{4}$	0 3	0 2 $\frac{3}{4}$	0 2 $\frac{3}{4}$
0 9	0 2 $\frac{3}{8}$	0 2 $\frac{3}{4}$	0 2 $\frac{3}{4}$	0 3	0 3 $\frac{1}{8}$	0 3 $\frac{1}{8}$	0 3 $\frac{1}{4}$	0 3 $\frac{1}{4}$
0 10	0 3 $\frac{1}{8}$	0 3 $\frac{1}{4}$	0 3 $\frac{1}{4}$	0 3 $\frac{1}{2}$	0 3 $\frac{1}{2}$	0 3 $\frac{3}{4}$	0 3 $\frac{3}{4}$	0 3 $\frac{3}{4}$
0 11	0 3 $\frac{1}{4}$	0 3 $\frac{1}{2}$	0 3 $\frac{1}{2}$	0 3 $\frac{3}{4}$	0 3 $\frac{3}{4}$	0 4	0 3 $\frac{3}{4}$	0 3 $\frac{3}{4}$

TABLE D (Feet).

	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Circumferences	1 0	2 0	3 0	4 0	5 0	6 0	7 0	8 0
Diameters	0 3 $\frac{1}{8}$	0 7 $\frac{1}{8}$	0 11 $\frac{1}{8}$	1 3 $\frac{1}{8}$	1 7 $\frac{1}{8}$	1 10 $\frac{1}{8}$	2 2 $\frac{1}{8}$	2 6 $\frac{1}{8}$
Cir.	9 0	10 0	11 0	12 0	13 0	14 0	15 0	16 0
Dia.	2 10 $\frac{1}{8}$	3 2 $\frac{1}{8}$	3 6 $\frac{1}{8}$	3 9 $\frac{1}{8}$	4 1 $\frac{1}{8}$	4 5 $\frac{1}{8}$	4 9 $\frac{1}{8}$	5 1 $\frac{1}{8}$
Cir.	17 0	18 0	19 0	20 0	21 0	22 0	23 0	24 0
Dia.	5 4 $\frac{1}{8}$	5 8 $\frac{1}{8}$	6 0 $\frac{1}{8}$	6 4 $\frac{1}{8}$	6 8 $\frac{1}{8}$	7 0 $\frac{1}{8}$	7 3 $\frac{1}{8}$	7 7 $\frac{1}{8}$
Cir.	25 0	26 0	27 0	28 0	29 0	30 0	31 0	32 0
Dia.	7 11 $\frac{1}{8}$	8 3 $\frac{1}{8}$	8 7 $\frac{1}{8}$	8 10 $\frac{1}{8}$	9 2 $\frac{1}{8}$	9 6 $\frac{1}{8}$	9 10 $\frac{1}{8}$	10 2 $\frac{1}{8}$
Cir.	33 0	34 0	35 0	36 0	37 0	38 0	39 0	40 0
Dia.	10 6 $\frac{1}{8}$	10 9 $\frac{1}{8}$	11 1 $\frac{1}{8}$	11 5 $\frac{1}{8}$	11 9 $\frac{1}{8}$	12 1 $\frac{1}{8}$	12 4 $\frac{1}{8}$	12 8 $\frac{1}{8}$
Cir.	41 0	42 0	43 0	44 0	45 0	46 0	47 0	48 0
Dia.	13 0 $\frac{1}{8}$	13 4 $\frac{1}{8}$	13 8 $\frac{1}{8}$	14 0 $\frac{1}{8}$	14 3 $\frac{1}{8}$	14 7 $\frac{1}{8}$	14 11 $\frac{1}{8}$	15 3 $\frac{1}{8}$
Cir.	49 0	50 0	51 0	52 0	53 0	54 0	55 0	56 0
Dia.	15 7 $\frac{1}{8}$	15 11	16 2 $\frac{1}{8}$	16 6 $\frac{1}{8}$	16 10 $\frac{1}{8}$	17 2 $\frac{1}{8}$	17 6 $\frac{1}{8}$	17 9 $\frac{1}{8}$
Cir.	57 0	58 0	59 0	60 0	61 0	62 0	63 0	64 0
Dia.	18 1 $\frac{1}{8}$	18 5 $\frac{1}{8}$	18 9 $\frac{1}{8}$	19 1 $\frac{1}{8}$	19 5	19 8 $\frac{1}{8}$	20 0 $\frac{1}{8}$	20 4 $\frac{1}{8}$
Cir.	65 0	66 0	67 0	68 0	69 0	71 0	71 0	72 0
Dia.	20 8 $\frac{1}{8}$	21 0 $\frac{1}{8}$	21 3 $\frac{1}{8}$	21 7 $\frac{1}{8}$	21 11 $\frac{1}{8}$	22 3 $\frac{1}{8}$	22 7 $\frac{1}{8}$	22 11 $\frac{1}{8}$

AND THEIR CIRCUMFERENCES
UP TO 200 FT CIRCUMFERENCE
 $\frac{1}{8}$ OF AN INCH IN DIAMETER.

TABLE D (Continued).

	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Circumferences	78 0	74 0	75 0	76 0	77 0	78 0	79 0	80 0
Diameters	23 $2\frac{3}{8}$	23 $6\frac{3}{8}$	23 $10\frac{3}{8}$	24 $2\frac{1}{8}$	24 $6\frac{1}{8}$	24 $9\frac{1}{8}$	25 $1\frac{1}{8}$	25 $5\frac{1}{8}$
Clr.	81 0	82 0	83 0	84 0	85 0	86 0	87 0	88 0
Dia.	25 $9\frac{1}{8}$	26 $1\frac{3}{8}$	26 $5\frac{3}{8}$	26 $8\frac{3}{8}$	27 $0\frac{1}{8}$	27 $4\frac{1}{8}$	27 $8\frac{1}{8}$	28 0
Clr.	89 0	90 0	91 0	92 0	93 0	94 0	95 0	96 0
Dia.	28 $3\frac{3}{8}$	28 $7\frac{3}{8}$	28 $11\frac{3}{8}$	29 $3\frac{3}{8}$	29 $7\frac{3}{8}$	29 $11\frac{1}{8}$	30 $2\frac{1}{8}$	30 $6\frac{1}{8}$
Clr.	97 0	98 0	99 0	100 0	101 0	102 0	103 0	104 0
Dia.	30 $10\frac{1}{8}$	31 $2\frac{1}{8}$	31 $6\frac{3}{8}$	31 $9\frac{3}{8}$	32 $1\frac{3}{8}$	32 $5\frac{1}{8}$	32 $9\frac{1}{8}$	33 $1\frac{1}{8}$
Clr.	105 0	106 0	107 0	108 0	109 0	110 0	111 0	112 0
Dia.	33 $5\frac{1}{8}$	33 $8\frac{1}{8}$	34 $0\frac{3}{8}$	34 $4\frac{1}{8}$	34 $8\frac{1}{8}$	35 $0\frac{3}{8}$	35 4	35 $7\frac{1}{8}$
Clr.	118 0	114 0	115 0	116 0	117 0	118 0	119 0	120 0
Dia.	35 $11\frac{1}{8}$	36 $3\frac{1}{8}$	36 $7\frac{3}{8}$	36 $11\frac{3}{8}$	37 $2\frac{3}{8}$	37 $6\frac{3}{8}$	37 $10\frac{1}{8}$	38 $2\frac{1}{8}$
Clr.	121 0	122 0	123 0	124 0	125 0	126 0	127 0	128 0
Dia.	38 $6\frac{3}{8}$	38 10	39 $1\frac{1}{8}$	39 $5\frac{3}{8}$	39 $9\frac{1}{8}$	40 $1\frac{3}{8}$	40 $5\frac{3}{8}$	40 $8\frac{1}{8}$
Clr.	129 0	130 0	131 0	132 0	133 0	134 0	135 0	136 0
Dia.	41 $0\frac{1}{8}$	41 $4\frac{1}{8}$	41 $8\frac{1}{8}$	42 $0\frac{3}{8}$	42 $4\frac{1}{8}$	42 $7\frac{3}{8}$	42 $11\frac{3}{8}$	43 $3\frac{1}{8}$
Clr.	137 0	138 0	139 0	140 0	141 0	142 0	143 0	144 0
Dia.	43 $7\frac{1}{8}$	43 $11\frac{1}{8}$	44 $2\frac{1}{8}$	44 $6\frac{1}{8}$	44 $10\frac{3}{8}$	45 $2\frac{1}{8}$	45 $6\frac{1}{8}$	45 $10\frac{3}{8}$
Clr.	145 0	146 0	147 0	148 0	149 0	150 0	151 0	152 0
Dia.	46 $1\frac{1}{8}$	46 $5\frac{1}{8}$	46 $9\frac{1}{8}$	47 $1\frac{3}{8}$	47 $5\frac{1}{8}$	47 $8\frac{3}{8}$	48 $0\frac{3}{8}$	48 $4\frac{1}{8}$
Clr.	153 0	154 0	155 0	156 0	157 0	158 0	159 0	160 0
Dia.	48 $8\frac{3}{8}$	49 $0\frac{1}{8}$	49 $4\frac{1}{8}$	49 $7\frac{1}{8}$	49 $11\frac{1}{8}$	50 $3\frac{1}{8}$	50 $7\frac{1}{8}$	50 $11\frac{3}{8}$
Clr.	161 0	162 0	163 0	164 0	165 0	166 0	167 0	168 0
Dia.	51 $2\frac{3}{8}$	51 $6\frac{3}{8}$	51 $10\frac{1}{8}$	52 $2\frac{1}{8}$	52 $6\frac{1}{8}$	52 $10\frac{1}{8}$	53 $1\frac{3}{8}$	53 $5\frac{3}{8}$
Clr.	169 0	170 0	171 0	172 0	173 0	174 0	175 0	176 0
Dia.	53 $9\frac{1}{8}$	54 $1\frac{1}{8}$	54 $5\frac{3}{8}$	54 9	55 $0\frac{1}{8}$	55 $4\frac{1}{8}$	55 $8\frac{1}{8}$	56 $0\frac{3}{8}$
Clr.	177 0	178 0	179 0	180 0	181 0	182 0	183 0	184 0
Dia.	56 $4\frac{3}{8}$	56 $7\frac{3}{8}$	56 $11\frac{3}{8}$	57 $3\frac{1}{8}$	57 $7\frac{1}{8}$	57 $11\frac{1}{8}$	58 3	58 $6\frac{3}{8}$
Clr.	185 0	186 0	187 0	188 0	189 0	190 0	191 0	192 0
Dia.	58 $10\frac{3}{8}$	59 $2\frac{1}{8}$	59 $6\frac{3}{8}$	59 $10\frac{3}{8}$	60 $1\frac{1}{8}$	60 $5\frac{1}{8}$	60 $9\frac{1}{8}$	61 $1\frac{3}{8}$
Clr.	193 0	194 0	195 0	196 0	197 0	198 0	199 0	200 0
Dia.	61 $5\frac{3}{8}$	61 $9\frac{3}{8}$	62 $0\frac{3}{8}$	62 $4\frac{1}{8}$	62 $8\frac{1}{8}$	63 $0\frac{1}{8}$	63 $4\frac{1}{8}$	63 $7\frac{1}{8}$

For explanation of Tables C and D, see page 272.

The diameter of circles of greater circumference than 200ft. may be found by taking the circumference in feet in two or more quantities, and adding the diameter for the inches in the ordinary way, thus :—

Required the diameter of a circle, the circumference being 281ft. 10½in.

By Table D . . 200ft. 0in. cir. = 63ft. 7½⁵/₈in. dia.

By Table D . . 81ft. 0in. cir. = 25ft. 9½³/₈in. dia.

By Table C . . 0ft. 10½in. cir. = 0ft. 3½¹/₈in. dia.

By combined Tables 281ft. 10½in. cir. = 89ft. 8½¹/₈in. dia.

The same example worked out by the standard .31831 by which the tables have been compiled is as follows :—

Circumference as given 281ft. 10½in.

12

3382.5 = Cir. reduced to inches.

.31831 = Standard.

3382.5

1.01475

27.0600

33.825

1014.75

12)1076.68357 5 inches dia.

89ft. 8.683575 inches.

In the Table of decimal equivalents for fractions of an inch on page 265 will be found .687500 as the equivalent for ⅙in. and the difference between .687500 and .683575 will show the amount of error in finding the diameter from the tables.

.687500

.683575

.003925 of an inch too little, or less
than ⅛in.

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DIAMETER

F

TABLE "A" shows diameters in millimetres (mm), from 1mm to 99 mm. and from 100mm. to 900mm. by 100's of mm's.

TABLE "B" shows diameters in metres (m) from 1 m to 50 m.

THE USE OF TABLE A

On the top line are shown diameters in millimetres, with their circumferences in the line directly below.

In the first column are shown diameters in tens of millimetres, with their circumferences in the second column.

On the last line are shown diameters in 100's of millimetres, followed by the appropriate circumferences in millimetres.

To find the circumference of a diameter between 1mm & 99mm, follow along the line on which the required tens of mms are shown in the first column to the column in which the required mms are shown at the top of the column. The circumference will be found in the "box" where the line and column meet.

For example—Circumference required where the diameter is given as 64 mm.

Follow along the line from 60 mm to the column under 4 mm where the circumference is shown as 201 mm.

To find the circumference of a diameter over 99mm., look along the bottom line for the hundreds of mm. required and the circumference will be found immediately adjacent.

For Example—Circumference required where the diameter is 347mm. Look along the bottom line for 300mm, when the circumference will be found to be 942mm. Then ascertain the circumference for 47mm, using the method outlined in the first example.

This figure—148mm—is then added to 942mm to obtain the required circumference—

$$\begin{array}{r} 942\text{mm} \\ 148\text{mm} \\ \hline 1,090\text{mm or } 1\text{m. } 90\text{mm} \end{array}$$

THE USE OF TABLE B

The table is laid out in five double lines of ten columns. Diameters in metres will be found on the top half of each double line, the corresponding circumference appearing on the bottom half.

For Example—If the circumference of a 35 metre circle is required, look along the fourth diameter line for the 35m diameter and the corresponding circumference of 109m 956mm will be found on the line immediately below.

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A Tables of Diameter From 1mm. to 99mm. and from

	mm	mm
mm	Diameters	1
Diameters		3
10	31	35
20	63	66
30	94	97
40	126	129
50	157	160
60	188	192
70	220	223
80	251	254
90	283	286
100mm	314mm	200mm
628mm	300mm	942mm

B Tables of Diameter From 1m. to 5

	m	mm	m	mm
Dia.	1	0	2	
Circumferences	3	142	6	28
Dia.	11	0	12	
Circ.	34	558	37	69
Dia.	21	0	22	
Circ.	65	974	69	11
Dia.	31	0	32	
Circ.	97	390	100	53
Dia.	41	0	42	
Circ.	128	806	131	94

Where a diameter is given in metres, and millimetres it will be necessary to use the two tables together as follows:—

Circumference required for a diameter of 23m 740mm:—

Using the methods outlined above, find the circumference corresponding to 23m, the circumference for 700mm and the circumference for 40mm and add the three figures together.

23m diameter	...	72m	257mm
700 mm diameter	...	2m	199mm
40mm diameter	...		126mm
		74m	582mm

In the example given above, the answer is correct to .42 of a millimeter, which is more than accurate enough for all practical applications. It must be emphasized, however, that if total accuracy required, for other than practical purposes, a calculation will be necessary (Diameter x 3.1416).

S AND THEIR CIRCUMFERENCES

r every 1mm. Diameter to 50m.

eters and their Circumferences for every 1mm. Diameter

100mm. to 900mm. — Calculated to the Nearest 1mm. in Circumference

mm	mm	mm	mm	mm	mm	mm	mm
2	3	4	5	6	7	8	9
6	9	13	16	19	22	25	28
38	41	44	47	50	53	57	60
69	72	75	79	82	85	88	91
101	104	107	110	113	116	119	123
132	135	138	141	145	148	151	154
163	167	170	173	176	179	182	185
195	198	201	204	207	210	214	217
226	229	232	236	239	242	245	248
258	261	264	267	270	273	276	280
289	292	295	298	302	305	308	311
400mm	1,257mm	500mm	1,571mm	600mm	1,885mm	700mm	2,199mm
800mm	2,513mm	900mm	2,827mm				

eters and their Circumferences for every 1m. Diameter

0 m. — Calculated to the Nearest 1mm. in Circumference

m	mm	m	mm	mm	m	m	mm	m	mm	m	mm	m	mm	m	mm
3	0	4	0	5	0	6	0	7	0	8	0	9	0	10	0
9	425	12	566	15	708	18	850	21	991	25	133	28	274	31	416
13	0	14	0	15	0	16	0	17	0	18	0	19	0	20	0
40	841	43	982	47	124	50	266	53	407	56	549	59	690	62	832
23	0	24	0	25	0	26	0	27	0	28	0	29	0	30	0
72	257	75	398	78	540	81	682	84	823	87	965	91	106	94	248
33	0	34	0	35	0	36	0	37	0	38	0	39	0	40	0
103	673	106	814	109	956	113	98	116	239	119	381	122	522	125	664
43	0	44	0	45	0	46	0	47	0	48	0	49	0	50	0
135	89	138	230	141	372	144	514	147	655	150	797	153	938	157	80

When making Bands or Tubes, the length required from butt to butt, or from centre to centre of holes, is the circumference at the Centre of the Thickness of the material. This means that actually half the thickness of the material should be deducted from each end of the plate before it is rolled, but, obviously, the same effect is achieved by deducting the whole of the thickness before making a calculation. For example — The circumference for a tube is required, the inside diameter of which is 1m 350mm and the thickness of the plate is 4mm. — Add the thickness of the plate to the inside diameter (1m 350mm + 4mm) making 1m 354mm, then from Table "B" establish the circumference for 1m, which is 3m 142mm and from "Table A" the circumference for 354mm which is 1m 112mm. The two circumferences thus established are added together:—

	3m	142mm
	1m	112mm
Total circumference	4m	254mm

If the outside diameter only is known, then the thickness of the material should be deducted from the outside diameter before looking up the tables.

